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Chapter IV

RETARDATION IN THE GROWTH OF INDUSTRIES

FOR some time, the notion has been commonly held that the percentage rates of growth of individual industries tend to decline as their age increases.[1] Some statistical support for this notion has already been given in the course of the analysis in the last chapter. Our aim now is to inquire more closely, and with the aid of sharper statistical tools, into the experiential foundations of the general doctrine of retardation in industrial growth. Accordingly, a comprehensive statistical test of this doctrine will be made, insofar as the data for this country since 1870 permit; and the statistical analysis will be followed by an inquiry into the causes of the drifts which the *rates* of growth of individual industries tend to exhibit. It will be seen that growth and decline in the rate of growth, so far as individual industries are concerned, go hand in hand in a progressive economy; that they jointly reflect the operation of forces which determine the growth of the total national dividend; that the theory of decline in the rates of growth of individual industries calls

[1] Tarde, Ogburn, and Chapin have explicated such a conception about the growth of 'inventions', or cultural units—among which industries are surely an important single form. See G. Tarde, *The Laws of Imitation* (translation by E. C. Parsons; Henry Holt, 1903), Ch. IV, especially pp. 115 and 127; W. F. Ogburn, *Social Change* (B. W. Huebsch, 1922), pp. 112–3; F. S. Chapin, *Cultural Change* (Century, 1928), Part IV. For statistical studies of industrial retardation, see Kuznets, *Secular Movements*, cited above, Chs. I–III; R. Prescott, "Law of Growth in Forecasting Demand," *Journal of the American Statistical Association*, December, 1922; and C. Snyder, *Business Cycles and Business Measurements* (Macmillan, 1927), Ch. II.

for merely an amplification of the theory of divergence in the long-term rates of growth; that several of the instances of acceleration in industrial growth reduce to retardation upon proper analysis; and that such instances of acceleration as are reliably established are indicative of the slackening of progressive forces.

I. MEASUREMENT OF RETARDATION

Whether an industry has been growing at a rising or declining percentage rate may, in most instances, be ascertained readily from a graph of its production, the quantities being plotted on a logarithmic scale and time on a natural scale. In all cases, a mathematical description of retardation can be obtained by fitting a curve—such as the simple logistic, the Gompertz, or the 'logarithmic' parabola—which will reveal a decrescent rate of growth. Our present purpose calls for a method sufficiently flexible to describe either retardation or acceleration in the growth of individual industries, and so constituted as to yield measures of the extent of the retardation or acceleration. These conditions are fulfilled admirably by the logarithmic parabola; this function may be either concave or convex, and the antilog of its second derivative expresses the average rate of retardation or acceleration. If the primary trends of production are now viewed in a different way than in the preceding chapter, that is only because a different problem is being investigated.[2]

The logarithmic parabola, that is, $\log y = c + (\log a)\,x + (\frac{\log b}{2})x^2$, reports directly through $\log b$ (which is the second derivative of $\log y$ with respect to x) the degree of retardation (or acceleration). A parabola fitted to logarithms of annual production data (x referring to years and y to production) reports through the constant $\log b$ the

[2] See Ch. II, sec. III, and Ch. III, sec. I.

average annual rate of retardation (or acceleration) of the logarithms of the production data; it gives an average in the sense that a parabola fitted to data generalizes or 'averages' the course of the series. The average annual percentage rate of retardation of the production data may now be obtained from the formula: $100\,(b-1)$. That this is the correct expression may be shown easily: Differentiating log y with respect to x, we get $\log Y = \log a + (\log b)x$. Taking antilogs, we have $Y = ab^x$. Since log b is at the same time the first derivative of the straight line and the second derivative of the parabola, the annual percentage rate of retardation is given by $100\,(\frac{ab^{x+1} - ab^x}{ab^x})$, which reduces to $100\,(b-1)$.

A logarithmic parabola may be fitted to production data by various methods. Though the method of least squares is most commonly used, another method was deemed preferable for this study. If we (1) view the decade rates of a given production series as observations at quinquennial dates on the rate of growth of that series, (2) write the decade rates in ratio form (for example, as 1.054 and not 5.4 per cent, and so on), (3) fit a straight line to the logarithms of these decade rates, the equation being $\log Y = \log a + (\log b)x$, where Y refers to the decade rates centered at quinquennial dates and x to quinquennial dates, and (4) integrate the equation (or, to express it roughly, cumulate the ordinates) of this straight line; we obtain the equation of a parabola fitted to the logarithms of the original data, except for the constant of integration which can be determined readily by invoking the criterion of the zero moment. However, since the average rate of retardation is given by the antilog of the second derivative of a logarithmic parabola, or by the antilog of the first derivative of the first derivative of the parabola, we can obtain this average rate directly from the antilog of the first derivative of the straight line fitted to the logarithms of the decade rates. Furthermore, since the antilog of log b, where log b is the first derivative of the above straight line, is equivalent to the term b in the exponential function $Y = ab^x$, our method of determining the average rate of retardation of a series consisted simply in calculating the value of the constant b in the exponential function $Y = ab^x$ (x referring to quinquennial dates and Y to decade rates centered at quinquennial dates), this type of curve being fitted by the method of moments[3] to the decade rates taken in ratio form.[4]

[3] See pp. 42-3.

[4] This method of measuring the average rate of retardation has three advantages. First, if we take the least squares method as a criterion, our method errs on the side of understatement of retardation; but as the backbone of the argument of this chapter stresses generality of actual retardation, a method of measurement which yields understatements of the extent of retardation lends firmer support to the conclusions reached. Second, the criterion of fit in our method is applied to the decade rates, while the criterion of fit in the method of least squares is applied to the logarithms of the original data. The consequence is that erratic movements in the original data exercise a smaller influence on an average rate of retardation calculated by our method than on one calculated by the least squares method. Third, the method adopted is much less laborious than the least squares method. With the decade rates at hand, it is a very simple matter to fit an exponential curve to them, especially when the method of moments, which does not involve the use of logarithms, is used. And as a matter of fact, it is not even necessary to determine in full the equation of the fitted exponential curve, for the constant which gives the rate of change suffices for our purpose.

A theoretical point remains to be noted. Let us assume that both actual production and production as observed through an empirical series trace out primary trends of the type of a 'logarithmic' parabola. Then, our method of measuring the rate of retardation will tend to 'compensate' for a downward retardation bias in production series, meaning by a downward retardation bias an overstatement by an empirical production series of the true retardation in actual production. On the other hand, the least squares method of measuring the rate of retardation will tend to 'compensate' for an upward retardation bias, meaning by that an understatement by the series of the true retardation. Hence, were it possible to appraise concretely our production series from the standpoint of their retardation bias, we could employ in each particular series that method which would compensate for the retardation bias in the original series. However, we are unable to appraise our series, from the standpoint of their retardation bias, with any assurance. It has, indeed, been possible to analyze our series in a general way from the standpoint of their growth bias (see pp. 25-7); but it is extremely hazardous to pass from the conclusions

The average rates of retardation (or acceleration) calculated for the various industries have been expressed in percentage form and on a decade basis. The decade rates being centered at quinquennial dates, the average percentage rate of retardation per decade is given by the formula: $100\left(\frac{ab^{x+2} - ab^{x}}{ab^{x}}\right)$, which reduces to $100(b^2 - 1)$. The average rate of retardation in the rate of growth of pig-iron production, for example, is recorded as −1.2 per cent per decade. The exact meaning of this is that the annual percentage rate of growth of the primary trend of pig-iron production had a downward drift such that the annual rate of growth (this is more conveniently expressed in ratio form) at any one time was .988 of the annual rate of growth ten years earlier. Thus the annual rate of advance of the primary trend of pig-iron output was 8.5 per cent in 1875, but only 7.2 per cent (determined from $1.085 \times .988$) in 1885, and 5.9 per cent (determined from $1.085 \times .988 \times .988$) in 1895, and so on. As the decade rates of most industries are not very high, it is not necessary to observe these niceties of interpretation. The exponential curves fitted to the decade rates of growth approach straight lines very closely in a preponderant number of the series. Hence, a rate of retardation of, let us say, −1.0 per cent may be interpreted to mean that the rate of advance of the primary trend of the given industry was, say, 5.0 per cent per year during one decade,

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reached concerning their growth bias to inferences concerning their retardation bias. All that we know with certainty is that if a series had a downward growth bias, at all points past or future, it would also have, at all points past or future, a downward retardation bias (or no retardation bias). This means that a production series having a downward growth bias during the period investigated will have of necessity also a downward retardation bias (or no retardation bias) during the period investigated, provided it is certain that the production series will continue to have a downward growth bias in the indefinite future. Obviously, this compass cannot be used with much assurance in seeking the theoretically preferable method of measuring the rate of retardation.

4.0 per cent per year during the next decade, 3.0 per cent during the next, and so on.

It should be observed that in the above examples of retardation, a negative sign is attached to the measures. This implies that a positive sign will be taken to denote acceleration. The present sign convention accords with mathematical usage, but is somewhat inconsistent with the name 'retardation' of the characteristic of production trends which is being investigated. In mathematical terms, we are throughout really measuring acceleration, positive or negative. All the same, the term retardation will be used generically to cover both retardation proper and acceleration, just as the term growth was used previously to cover both growth proper and decline. The justification of this terminology lies in the economic facts considered—that is, the generality of the phenomena of actual growth, and of actual decline in the rate of growth. Whether the term retardation is used generically or merely to cover the cases of actual decline in the rate of growth will be clear in each particular instance.

The average rates of retardation have been supplemented by another set of measures, which serve, first, to make clearer the graphic meaning of the rates of retardation,[5] and second, to indicate the stage reached in the development of the various industries. These supplementary measures are, in effect, the dates at which 'logarithmic' parabolas fitted to the original production data pass through maxima. In our method of procedure, it was necessary merely to find the dates at which the ordinates of the exponential curves fitted to the decade rates of the individual series are equal to unity.[6] These dates may, of course, define either maxima or

[5] The term 'rate of retardation' is used synonymously with 'average rate of 'retardation' throughout this chapter, and also in section III of Chapter VI. Similarly, the phrases 'retardation in growth' and 'decline in the rate of growth' are used synonymously.

[6] The value of x which will maximize the function $\log y = c + (\log a)x$

minima; but the dates have been computed only when they defined maxima—that is, they have been restricted to the series which show actual retardation in their growth. The dates of parabolic maxima will be referred to as measures of the stage of retardation. If the rate of retardation of one industry is −2.0 per cent per decade, and of another −1.0 per cent, but both have parabolic maxima in 1940, there is some ground for considering their relative stages of development to be the same, even though the rate of retardation of the one is twice that of the other.

The calculated parabolic turning dates are descriptions based on particular segments of economic history, as are the measures of the average rate of retardation, which the parabolic turning dates supplement.[7] The parabolic turning dates are not to be interpreted as predictions when industries will cease to grow, or as statements that they have already passed their zenith. Of course, the implications of the measures extend beyond the specific periods studied, but that is quite another thing from attaching significance to any extrapolations of specific numerical results. To guard against any misuse of the calculated parabolic turning dates, they are presented in the form of deviations from the year 1930. Thus, the measure of the stage of retardation of pig-iron production

$+ \left(\frac{\log b}{2}\right) x^2$ may be obtained by equating its first derivative to 0. Doing this, we have $\log Y = \log a + (\log b)x = 0$. Or, taking antilogs, $Y = ab^x = 1$. Of course, the dates of parabolic maxima obtained from exponential curves fitted to the decade rates are not necessarily identical with those which would be yielded by parabolas fitted directly to the logarithms of the original data by the method of least squares.

7 The average rates of retardation hold strictly for only the specific periods covered by the series. It goes without saying that the measures may differ considerably, if somewhat different periods are analyzed. Thus, the rate of retardation of total coal production is −1.4 per cent per decade for 1870–1929, −0.9 per cent for 1850–1929, and −1.7 per cent for 1820–1929. Rates of retardation are generally cited in later pages as so many 'per cent', but they are always to be understood as so many 'per cent per decade'.

is stated to be 13 years, which means that the date of its parabolic maximum is 1943; and the measure of the stage of retardation of roofing slate is stated to be –25, which means that the date of its parabolic maximum is 1905.

The descriptive significance of measures of the rate and stage of retardation of a given production series is conditioned by the adequacy with which an exponential curve fits the decade rates of the series.[8] If a satisfactory fit is obtained, the measure of stage of retardation will also be satisfactory. However, though an average rate of retardation will gain in significance when the fit is satisfactory, its true significance depends further on the degree of continuity in the march of retardation. Accordingly, a measure of the continuity of retardation has been determined for each series. This measure expresses the excess of positive over negative first differences of the decade rates of a series as a ratio to the number of first differences,[9] and therefore has a theoretical range from -1 to $+1$: it will be -1 when retardation is continuous, that is, when each decade rate is lower than the preceding one; it will be $+1$ when acceleration is continuous, that is, when each decade rate is higher than the preceding one; it will be 0 when the number of decade rates higher than those preceding them is exactly the same as the number of decade rates lower than those preceding them. To cite two examples,

[8] Satisfactory fits were obtained in a preponderant number of series, but not in all series. Perhaps the most conspicuous of the poor 'fits' are those for the production of sulphur and of non-Portland cements, whose measures of retardation are therefore largely nominal.

[9] The decade rates were taken as centered at successive quinquennial dates. Since the decade rates are imperfect measures (see pp. 40–1, note 13), the range of error in the first differences of the decade rates will be greater than in the decade rates proper. Even though the measure of continuity takes account of only the signs of the first differences, it may still be unreliable when the decade rates of a series are highly similar. First differences of zero were ignored in determining the numerator of the ratio in the measure of continuity; this is tantamount to counting zeroes as half-positive and half-negative.

the measure of continuity of retardation is —.30 for pig iron, and —.25 for roofing slate.

Our measures of industrial retardation comprise, then, the average rate of retardation, the stage of retardation, and the continuity of retardation. These measures have been determined for the full period covered by each series. The primary reason for having the several measures of retardation cover the longest interval possible, within the limits of the period investigated, is that the distorting influence of trend-cycles on the measures is in this way reduced. In the preceding chapter, average rates of growth were presented for the period 1885–1929, which the series cover in common, as well as for the full period covered by each series, for the reason that the existence of a drift in the decade rates of the individual series would have seriously affected any comparisons of average rates of growth over periods of variable duration. But there is no such compelling reason for clinging to the same time interval for each series in a study of retardation. Moreover, as the series analyzed run over intervals varying from 45 to 60 years, all falling within the period since about 1870, their time reference is sufficiently similar to insure ample comparability for the present purpose.

II. THE STATISTICAL EVIDENCE

The first part of the inquiry in this chapter is a statistical report which attempts to answer the questions: To what extent is a decrescent rate of growth of individual industries a general phenomenon? How rapid is retardation generally? To what extent is retardation continuous in the individual industries? In seeking to establish the facts, average rates of retardation were determined for the 104 continuous series considered in the preceding chapter, and for 43 additional series of discontinuous data; measures of continuity of retardation were determined for all of the continuous series;

and measures of stage of retardation, for those continuous series which show actual retardation. The several measures of retardation for the individual series are recorded in Tables 22–25, which give also the periods covered by the series.

The rates of retardation of 142 production series are summarized in Table 19 and Chart 2.[10] A mere glance at the chart or table will suffice to reveal that a preponderant number of the industries have grown at a declining rate. Furthermore, though the rates of retardation vary considerably, their general level is fairly high. Of the 142 series included in Table 19, as many as 122 have rates of retardation in excess of –0.2 per cent per decade, which is the average rate of retardation in the population growth of this country since 1870.[11] It is difficult to escape the conclusion that retardation in the growth of production has been almost universal among the industries covered, and that the rapidity of retardation has been, on the whole, quite appreciable.

Measures of the stage of retardation, recorded in Tables

10 This group of 142 series consists of 99 continuous series (the 'all' series group,—see Appendix A, Table 46, column *e*) and 43 discontinuous series (these are starred in Tables 22–25). Although discontinuous series cannot be used generally in analyzing the characteristics of production trends, they satisfy in most instances the purpose of indicating the presence or absence of retardation and its approximate extent; so, by using these series, it has been possible to extend considerably the range of industrial observation. In order to insure comparability, the rates of retardation for the discontinuous series were determined by the same method as the rates for the continuous series, except that the preliminary 'decade rates' were determined for successive decades only. Various makeshifts were necessary, of course, in applying the method. Thus, in the case of data available for decennial dates only, geometric average annual rates of growth were calculated, and similarly, when data were given at quinquennial intervals. When data were available at more frequent intervals, Glover's 'mean value table' was used for annual, biennial, or triennial data, according to the fullness of the record. Whenever possible, corrections were made for the cyclical factor. The exact procedure differed from series to series and little would be gained by detailing what was done in each case. Once approximations to 'decade rates' were reached, exponential curves were fitted to them to yield measures of retardation. For the sources of the discontinuous series and brief descriptive notes, see Appendix B, II.

11 See p. 262, note 11, concerning data on population, and this chapter, note 10, concerning method of measuring its retardation.

22–25, bear further witness to the magnitude of retardation in the industries covered. Of the 104 continuous series, 92 show abatement in their rates of growth; and of these 92

Table 19

FREQUENCY DISTRIBUTION OF AVERAGE RATES OF RETARDATION, FOR 142 PRODUCTION SERIES

Average rate of retardation (per cent per decade)	Number of series	Percentage of series
Below –6.2 *	1	0.7
–6.2 to –5.8	3	2.1
–5.7 to –5.3	..	...
–5.2 to –4.8	3	2.1
–4.7 to –4.3	..	...
–4.2 to –3.8	4	2.8
–3.7 to –3.3	6	4.2
–3.2 to –2.8	3	2.1
–2.7 to –2.3	11	7.7
–2.2 to –1.8	13	9.2
–1.7 to –1.3	16	11.3
–1.2 to –0.8	37	26.1
–0.7 to –0.3	25	17.6
–0.2 to 0.2	5	3.5
0.3 to 0.7	8	5.6
0.8 to 1.2	4	2.8
1.3 to 1.7	1	0.7
1.8 to 2.2	1	0.7
2.3 to 2.7	..	...
2.8 to 3.2	1	0.7
Total	142	100.0

* The item in this class is –11.5.

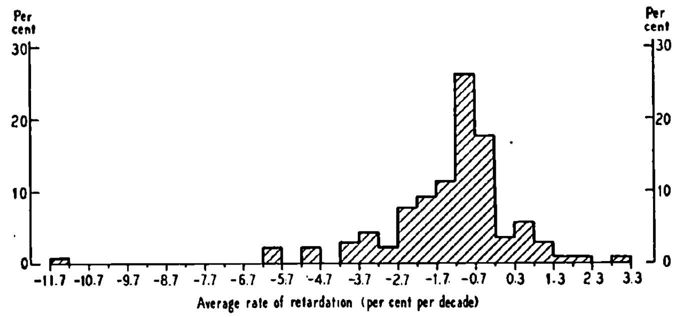
series, 9 have parabolic maxima in 1910 or earlier, 21 in 1920 or earlier, and 45 in 1930 or earlier. Of course, not all of these industries can be considered to have actually passed their apex, but it is equally likely that certain others have already done so.[12] Speaking very roughly, the industries

12 Thus, the summits of aluminum and steel production are probably in the

which have experienced the most rapid rates of retardation are also in the most advanced stages of retardation. Thus, all but 4 of the 15 series having the highest rates of retardation have parabolic maxima before 1930, while all but 3 of the 15 series having the lowest rates of retardation have parabolic maxima some time after 1930. The measures of stage of retardation suggest that a considerable number of the industries surveyed have already passed their zenith. In this sense, they corroborate the evidence of the rates of retardation, which are generally of a rather high order of magnitude.

Chart 2

FREQUENCY DISTRIBUTION OF AVERAGE RATES OF RETARDATION OF 142 PRODUCTION SERIES



But though retardation has been a general phenomenon and its intensity fairly marked, its march has not been continuous, as Table 20 shows, in any of the industries surveyed. However, most of the measures of continuity of retardation are negative in sign; this indicates that retardation has dominated over acceleration in the decade-by-decade movements of the individual series, and lends support to the rates of retardation. As is to be expected, the measures of continuity

distant future; but the actual peaks of rail consumption and railway passenger traffic come earlier than their dates of parabolic maxima, and it is improbable that these peaks will be surpassed in the reckonable future.

Table 20

FREQUENCY DISTRIBUTION OF MEASURES OF CONTINUITY OF RETARDATION, FOR 'ALL' SERIES

Measure of continuity of retardation	Number of series
–.89 to –.70	3
–.69 to –.50	13
–.49 to –.30	18
–.29 to –.10	28
–.09 to .10	27
.11 to .30	4
.31 to .50	6
Total	99
Below 0.0	62
0.0	27
Above 0.0	10
Total	99

of retardation are roughly correlated with the measures of the rate of retardation. But the relation between the two measures is not very close, as may be gathered from these facts: only 3 of the 12 series having the highest (negative) measures of continuity of retardation are found among the 12 series having the highest rates of retardation,' and the signs of the two measures are reversed in as many as 9 series. The inconstancy of retardation, registered in the measures of continuity of retardation, arises from the undulatory movements of production trends, which are analyzed in the next chapter.

The details of the statistical evidence of industrial retardation are in some ways more interesting than the general tenor of the evidence. Attention will be confined in the remaining portions of this section to the average rates of retardation, which may be significantly approached from the

Table 21

FREQUENCY DISTRIBUTIONS OF AVERAGE RATES OF RETARDATION, FOR 142 PRODUCTION SERIES, BY INDUSTRIAL GROUPS

Average rate of retardation (per cent per decade)	(1) Agriculture, fisheries, and forestry	(2) Mining	(3) Manufactures and construction	(4) Transportation and trade	(5) Nonagricultural industries (2)+(3)+(4)	(6) All industries (1)+(5)
Below −6.2 *	..	..	1	..	1	1
−6.2 to −5.8	1	1	1	..	2	3
−5.7 to −5.3	..	..	..	..	..	..
−5.2 to −4.8	..	1	2	..	3	3
−4.7 to −4.3	..	..	..	..	..	..
−4.2 to −3.8	..	1	3	..	4	4
−3.7 to −3.3	1	..	5	..	5	6
−3.2 to −2.8	1	..	2	..	2	3
−2.7 to −2.3	..	3	7	1	11	11
−2.2 to −1.8	2	3	8	..	11	13
−1.7 to −1.3	1	4	7	4	15	16
−1.2 to −0.8	12	4	19	2	25	37
−0.7 to −0.3	10	2	12	1	15	25
−0.2 to 0.2	2	1	1	1	3	5
0.3 to 0.7	1	..	5	2	7	8
0.8 to 1.2	1	..	2	1	3	4
1.3 to 1.7	..	..	1	..	1	1
1.8 to 2.2	..	..	..	1	1	1
2.3 to 2.7	..	..	..	..	..	..
2.8 to 3.2	..	..	1	..	1	1
Total	32	20	77	13	110	142

* The item in this class is −11.5.

standpoint of different resource groups of industries. The rates of retardation of the 142 production series earlier considered are distributed in Table 21 into four main divisions. It will be noticed that the series of organic materials (agriculture, fisheries, and forestry) do not exhibit, on the average, such extensive retardation as do the series in the other divisions, except transportation and trade. The rates of retardation of the organic materials are also more definitely concentrated within a narrow range than the rates of the series in any of the other divisions: approximately two-thirds of the organic materials series, but only about two-fifths of the series in each of the other industrial divisions, are included in the one per cent interval of greatest concentration on the several scales of retardation. The distinctive character of the frequency distribution of the rates of retardation of organic materials is revealed most sharply when it is contrasted with the corresponding distribution of the 'nonagricultural' group, which is a combination of the divisions of mining, manufactures and construction, and transportation and trade.

The rates of retardation of the individual series of organic raw materials and inorganic raw materials are stated respectively in Tables 22 and 23. The record of the minerals group is quite striking, as the production of each of the minerals has grown at a decrescent rate. Three series in the organic materials group evidence acceleration, but these series are of minor importance; and it is also of some interest that two of them—cod and mackerel tonnage, and whale tonnage—relate to decadent industries, their acceleration meaning a decline in the rate of decadence. The more important mineral and agricultural products generally have medial rates of retardation, though there are such conspicuous exceptions as petroleum and Portland cement. What is most significant now is that a tendency towards abatement in the rate of growth is evidenced almost without exception by the rather extensive production records of individual raw materials. This generalization may be safely extended to the class of individual raw materials, since a very large portion of the entire field of raw material production is covered by our statistics.

The rates of retardation of the series of manufactures are set forth in Table 24, the two construction series—building

Table 22

RETARDATION IN THE GROWTH OF INDUSTRIES: AGRICULTURE, FISHERIES, AND FORESTRY

Series	Period covered by series	Measures of retardation		
		Average rate (per cent per decade)	Continuity	Stage (years from 1930)
Raisins	1872–1929	–6.2	–.20	– 7
Beet sugar	1870–1929	–3.4	–.40	14
Cane sugar	1870–1929	–2.8	–.40	–27
Molasses and sirup	1870–1929	–1.8	–.20	–19
*Hemp	1869–1929	–1.8	...	...
Cattle	1880–1929	–1.7	–.25	– 6
Oats	1870–1930	–1.2	–.10	– 7
Buckwheat	1870–1929	–1.1	.00	–26
Sheep	1880–1929	–1.1	.00	– 4
*Broom corn	1879–1929	–1.1	...	...
Corn	1870–1929	–1.0	–.70	–14
Hay	1870–1930	–1.0	–.30	–10
*Honey	1869–1929	–1.0	...	...
Rye	1870–1929	–0.9	–.20	– 6
*Lumber	1869–1929	–0.9	...	...
*Sweet potatoes	1869–1930	–0.9	...	...
Cotton	1870–1929	–0.8	.00	2
Wool	1870–1929	–0.8	.20	–14
Potatoes	1870–1929	–0.7	–.40	– 4
Barley	1870–1929	–0.7	–.20	19
Flaxseed	1879–1929	–0.6	.00	11
*Maple sugar	1869–1930	–0.6	...	...
Wheat	1870–1930	–0.5	–.40	– 5
*Butter	1879–1929	–0.5	...	...
*Hops	1869–1929	–0.5	...	...
Hogs	1880–1929	–0.4	–.50	35
Rice	1870–1929	–0.4	–.40	93
Tobacco, raw	1870–1929	–0.3	–.30	36
Fish, total	1880–1929	–0.1	.50	143
Cod and mackerel	1870–1929	0.1	.00	...
*Beans, dry, edible	1879–1929	0.4	...	...
Whale	1870–1929	0.8	.00	...

*The data are discontinuous.

Table 23

RETARDATION IN THE GROWTH OF INDUSTRIES: MINING

Series	Period covered by series	Measures of retardation: Average rate (per cent per decade)	Continuity	Stage (years from 1930)
Portland cement......	1880–1929	–5.9	–.50	3
Pyrites	1880–1929	–4.9	–.25	–14
Asphalt	1880–1929	–4.1	–.50	5
Phosphate rock........	1870–1929	–2.5	–.50	– 3
Fluorspar.............	1880–1929	–2.3	.00	8
Sulphur	1880–1929	–2.3	.00	58
Copper	1870–1929	–2.2	–.60	3
Natural gas...........	1882–1929	–2.1	.00	13
Iron ore..............	1880–1929	–1.9	–.25	– 1
Zinc.................	1870–1929	–1.7	–.60	10
Bituminous coal	1870–1929	–1.6	–.40	3
Lead, domestic........	1870–1929	–1.6	.00	3
Coal, total............	1870–1929	–1.4	–.60	2
Anthracite coal........	1870–1929	–1.4	–.40	–14
Cement. total	1880–1929	–1.3	.00	37
Silver................	1870–1929	–1.1	–.20	–12
Salt..................	1880–1929	–1.0	.00	22
Gypsum...............	1880–1929	–0.9	–.25	57
Gold.................	1870–1929	–0.9	–.20	–26
Mercury..............	1870–1929	–0.5	.00	–63
Petroleum	1870–1929	–0.3	–.10	186
Non-Portland cements..	1880–1929	–0.2	–.25	–20

permits and rail consumption—being included along with the manufactures. The rates of retardation of the manufactures are even more variable than the rates of the minerals. The antipodal positions are occupied by two rather new industries, each of which has experienced remarkable expansion: aluminum production has the highest rate of retardation, and light petroleum distillates the highest rate of acceleration. The industries whose rates of growth have

Table 24

RETARDATION IN THE GROWTH OF INDUSTRIES: MANUFACTURES AND CONSTRUCTION

Series	Period covered by series	Measures of retardation		
		Average rate (per cent per decade)	Continuity	Stage (years from 1930)
Aluminum	1883–1929	–11.5	–.43	– 6
*Wood pulp	1869–1929	– 5.9	...	...
*Paraffin oils	1879–1929	– 4.9	...	...
*Paraffin wax	1879–1929	– 4.8	...	...
Cottonseed oil	1872–1929	– 3.8	–.60	–10
Cottonseed cake and meal	1872–1929	– 3.8	–.60	– 8
Sisal imports	1870–1929	– 3.8	–.20	–15
*Harrows, other than disk	1869–1929	– 3.5	...	...
Steel	1870–1929	– 3.4	–.60	– 1
*Broad silks	1869–1929	– 3.4	...	...
*Shirts and drawers, knit	1869–1929	– 3.4	...	...
*Gloves and mittens, knit	1869–1929	– 3.3	...	...
Locomotives	1880–1929	– 3.1	.00	–28
*Plate glass, polished	1879–1929	– 3.0	...	...
Roofing slate	1879–1929	– 2.7	–.25	–25
*Mowers	1869–1929	– 2.7	...	...
Antimonial lead	1871–1929	– 2.6	–.40	– 4
Canned tomatoes	1885–1929	– 2.3	–.71	– 7
*Boards paper	1879–1929	– 2.3	...	...
*Fertilizers	1869–1929	– 2.3	...	...
*Shingles	1869–1929	– 2.3	...	...
Coke	1880–1929	– 2.2	–.25	– 1
*Newsprint and book paper	1879–1929	– 2.1	...	...
Superphosphate	1870–1929	– 2.0	–.40	3
*Condensed and evaporated milk	1879–1929	– 2.0	...	...
*Sulphuric acid	1879–1929	– 2.0	...	...
*Structural shapes	1879–1929	– 1.9	...	...
Minor fiber imports	1870–1929	– 1.8	.00	–15
Lead, total	1870–1929	– 1.8	.00	1
Canned corn	1885–1929	– 1.8	.29	4

Table 24 (cont.)

RETARDATION IN THE GROWTH OF INDUSTRIES: MANUFACTURES AND CONSTRUCTION

Series	Period covered by series	Measures of retardation		
		Average rate (per cent per decade)	Continuity	Stage (years from 1930)
Silver consumption	1880–1929	− 1.7	−.25	3
Jute imports	1870–1929	− 1.7	−.20	−23
Fermented liquors	1870–1918	− 1.5	−.25	− 8
Copper consumption ...	1883–1929	− 1.4	.14	19
*Common brick	1869–1929	− 1.4	...	...
Cigars	1880–1929	− 1.3	−.37	−14
*Hay rakes	1869–1929	− 1.3	...	...
Pig iron	1870–1929	− 1.2	−.30	13
*Laths	1869–1929	− 1.2	...	...
*Walking plows	1869–1929	− 1.2	...	...
Tobacco and snuff.....	1871–1929	− 1.1	−.40	− 7
Tin imports...........	1870–1929	− 1.1	−.20	10
White lead............	1884–1929	− 1.1	−.14	− 4
Vessels	1870–1929	− 1.1	.00	−32
*Zinc oxide...........	1880–1929	− 1.1	...	...
Zinc consumption	1873–1929	− 1.0	−.56	35
Rails.................	1870–1929	− 1.0	−.20	− 7
*Hosiery	1869–1929	− 1.0	...	...
Nails.................	1872–1929	− 0.9	−.60	− 3
Building permits.......	1874–1929	− 0.9	−.33	24
*Lumber consumption .	1869–1929	− 0.9	...	...
*Window glass	1879–1929	− 0.9	...	...
Tin-plate consumption .	1871–1929	− 0.8	.00	38
Cocoa imports	1870–1929	− 0.8	.00	75
Wool consumption	1870–1930	− 0.8	.40	− 9
*Wrapping paper......	1879–1929	− 0.8	...	...
Gold consumption	1880–1929	− 0.7	−.50	35
Rolled iron and steel ...	1885–1929	− 0.7	−.14	38
Flour	1880–1929	− 0.7	.00	− 4
Silk imports, raw	1870–1929	− 0.7	.00	99
Cotton consumption ...	1870–1929	− 0.6	−.20	28
*Grain drills	1869–1929	− 0.6	...	...
Coffee imports	1870–1929	− 0.5	−.20	40
Manila hemp imports ..	1870–1929	− 0.5	.00	4
*Boots and shoes	1869–1929	− 0.5	...	...
*Cotton, woven goods..	1879–1929	− 0.4	...	...
Raw sugar consumption	1870–1930	− 0.3	.40	54

Table 24 (cont.)

RETARDATION IN THE GROWTH OF INDUSTRIES: MANUFACTURES AND CONSTRUCTION

Series	Period covered by series	Measures of retardation		
		Average rate (per cent per decade)	Continuity	Stage (years from 1930)
Lead consumption	1870–1929	− 0.3	.40	163
*Fine paper	1879–1929	− 0.3	...	...
Tobacco consumption	1880–1929	− 0.2	−.50	97
Rail consumption	1870–1929	− 0.2	.00	46
Cigarettes	1880–1929	0.3	−.25	...
Flaxseed consumption	1879–1929	0.3	.00	...
*Face brick	1879–1929	0.5	...	...
Distilled spirits	1870–1918	0.6	.00	...
Silk imports, unmanufactured	1883–1929	0.6	.43	...
*Burning oils	1879–1929	0.8	...	...
*Hay loaders	1879–1929	1.0	...	...
Rubber imports	1870–1929	1.6	.20	...
*Light petroleum distillates	1879–1929	3.1	...	...

*The data are discontinuous.

declined most rapidly are, in many instances, rather specific manufactures. Series representative of broad classes of manufacture—for example, zinc consumption, copper consumption, lead consumption, tin imports, cotton consumption, tobacco consumption, and rolled iron and steel—are not found among those with extreme rates of retardation. There is some tendency for the rates of retardation of industries producing consumers' goods to cluster at the bottom of the list, but there is not nearly the same tendency for the rates of retardation of producers' goods series to cluster in the upper portion of the list. Only nine series of manufactures evidence accelerated growth; but the present cases are found among progressive industries, some of which are also of great importance. While several[13] of these instances of acceleration are traceable to economic causes of profound importance, others [14] are of doubtful reliability.

Certainly, most of our series of manufactures disclose declining rates of growth. But the important question is whether or not it is proper to extend this generalization for our series to the class of individual manufactures. According to our estimate, the coverage of the continuous series of manufactures amounts to only about 22 per cent of the output of all manufactures in 1925; and even with the industrial coverage of the discontinuous series added, the representation of manufactures is only about 32 per cent.[15] These figures, however, are somewhat misleading; for they ignore the considerable indirect representation of the series, understate the coverage for early years, and are not restricted to that portion of the production area which is common to the entire period surveyed.[16] The series which have been analyzed relate to widely varying branches of manufacture, some refer to groups of commodities and others to fairly specific products, some to commodities of large industrial importance and others to products of very minor consequence: the extent and the variety of the series create a strong presumption that a generalization holding for them will hold for individual manufactures as a class.

The measures of retardation for such series as are indicative of transportation and trade are assembled in Table 25. As five of the thirteen series in this group show acceleration, it might possibly appear that retardation has been less general in this industrial division than in the others. However,

[13] Cigarettes, face brick, burning oils, rubber imports, and light petroleum distillates; see pp. 154–5.

[14] See Appendix C, II.

[15] For the estimates of the coverage of the continuous series, see pp. 18–20. The coverage of the discontinuous series has been estimated by the same method as the coverage of the continuous series.

[16] In a sense, the really important comparison is between the industries

Table 25

RETARDATION IN THE GROWTH OF INDUSTRIES: TRANSPORTATION AND TRADE

Series	Period covered by series	Measures of retardation		
		Average rate (per cent per decade)	Continuity	Stage (years from 1930)
S. S. Marie canals traffic	1870–1929	−2.7	−.40	0
Railway ton-miles	1870–1929	−1.4	−.40	12
Railway freight	1882–1929	−1.4	.00	5
Railway passenger-miles	1882–1929	−1.3	−.75	− 1
Agricultural exports ...	1870–1929	−1.3	.00	−16
Postal money orders ...	1870–1929	−1.2	−.60	33
*Snyder's index of trade	1870–1930	−0.8	...	...
Deflated clearings	1870–1929	−0.3	−.20	96
Tonnage entered and cleared	1870–1929	0.1	.00	...
Postage stamps	1870–1929	0.3	−.10	...
Coastal trade	1870–1929	0.4	.00	...
N. Y. canals traffic	1870–1929	0.8	.00	...
Shares traded	1875–1929	2.2	.33	...

*The data are discontinuous.

the acceleration is limited to series which are statistically defective,[17] or of minor industrial importance, or both. One of the minor series—New York canals traffic—is of special interest because it provides an additional instance of a de-

covered and those which could have been covered. It would be extremely difficult to estimate this ratio; but it is obvious that the ratio must be considerably higher than the estimate of the industrial coverage of our series. Then again, certain industries whose statistical (and occasionally, economic) history does not go back to 1885—oleomargarine, electricity, railway passenger and freight cars, motor vehicles, rayon, and a few others—also disclose declining rates of growth. But the statistical records of some of these industries are too short to yield reliable results: short series for new industries, even when they extend back to the very nascence of the industries, may have a retardation which is more arithmetic than economic in significance (see p. 120); while short series for old industries may reflect little more than a dominant phase of their trend-cycles (see Ch. V).

[17] See Appendix C, II.

clining industry showing algebraically a rising rate of growth. It is probably true that most of the individual industries performing transport or trade functions have grown at a decrescent rate, but such a generalization cannot confidently be drawn from the series covered.

This much, then, can be said in summary about the industrial incidence of retardation during the period since 1870 or so. Retardation has taken place in a preponderant number of the industries covered in our survey;[18] its extent in the individual industries has been on the whole rather high; but its march has not been continuous, because of the 'interference' of cycles in the secular trends with the downward drift of the rates of growth. There is considerable evi-

[18] It has already been pointed out that several accelerative series are defective from the standpoint of the use to which they are put in this chapter (some evidence is presented in Appendix C, II), and that certain other accelerative series express the influence of profound economic causes (see pp. 153–5). All the same, the question is of some interest whether the seventeen series (among the 147 distributed through Tables 22–25) showing acceleration would continue to do so if the period of observation were extended.

It is possible to carry back the statistical records of only eight of the accelerative series: New York canals traffic, tonnage entered and cleared, coastal trade, postage stamps, cod and mackerel tonnage, whale tonnage, production of dry beans, and cigarette production. (The series of cigarette production used in this study begins in 1880; but estimates of cigarette production, made by W. W. Young, *The Story of the Cigarette*, Appleton, 1916, p. 115, on the basis of tax receipts, are available for 1869–79. The series 'dry beans' used in this study begins in 1879; but estimates for census years back to 1849 have been made by Warren and Pearson, *The Physical Volume of Production in the United States*, Cornell University Agricultural Experiment Station, Memoir 144, p. 40. Though the estimates for these two series are too uncertain to warrant general use, they are adequate for the purpose of a splicing whose aim is to indicate whether or not retardation has been present. All the other series which are extended are carried back of 1870, their initial date in this work. Data for distilled spirits can also be carried back, but only to 1863; this is too small an extension to be worth making.)

So far as New York canals traffic, the cod and mackerel fisheries, and the whale 'fishery' are concerned, it is altogether superfluous to resort to quantitative measurements. The summit of these industries has long been passed: the peak of New York canals traffic was reached around 1870, in the mackerel fishery in the early 'eighties, probably somewhat earlier in the cod fishery, and about 1850 in the whale 'fishery'. It goes without saying that if the record of dence that most of the individual industries in agriculture, mining, and manufacture have experienced abatement in their rates of growth. In all likelihood, this is true as well of the individual branches of forestry, the fisheries, construction, transportation, and trade. Little is known about other industrial divisions, such as banking, and the various professional and personal services, except that these fields of productive endeavor have greatly expanded. No attempt has been made to determine whether or not the individual branches of these service industries have grown at declining rates, as practically no statistics of their production are available, except the very indirect and not altogether comparable data contained in the federal censuses of occupations.[19]

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these industries were carried back of the dates of their highest development, very considerable retardation in their growth would become evident. The five remaining series—tonnage entered and cleared, coastal trade, postage stamps, dry beans, and cigarettes—represent progressive industrial activities. Four of these series evidence a declining rate of growth, when their full statistical history is analyzed: for the period 1869–1929, 'cigarettes' show a rate of retardation of -3.6 per cent (see p. 155); for 1852–1929, 'postage stamps', -1.0 per cent; for 1821–1929, 'tonnage entered and cleared', -0.2 per cent; and for 1790–1929, 'coastal trade', -0.3 per cent. The series 'dry beans' shows a rate of acceleration of 0.4 per cent for 1879–1929, but only 0.1 per cent for 1849–1929. There are, then, some statistical indications that when the period under observation is extended, the various instances of acceleration reduce to retardation. Incidentally, the extensions show how careful one must be in interpreting the rates of retardation, which are in the nature of averages for specific time intervals.

It is not proper to carry back the statistical records of only those industries which evidence acceleration. Obviously enough, if the records of the industries showing retardation were also carried back, it might develop that some of them show acceleration for the longer period. In order to test for this possibility, the statistics of lead, copper, zinc, pig iron, petroleum, rails, vessels, total coal, railway ton-miles, and cotton consumption were extended back of 1870 (there are very few other series which go back of 1870). Each of these series discloses a declining rate of growth, when the entire period of its statistical history is investigated.

19 Such data do show retardation; see Hurlin and Givens, cited above, pp. 271–304. For a further statistical analysis of retardation in individual industries, see pp. 163–9. Concerning the problem of retardation in the growth of total production, see Ch. VI, sec. III.

III. THE EXPLANATION OF INDUSTRIAL RETARDATION

The foregoing statistical conclusions accord nicely with common intuitions about the course of industrial development. That industries rise and decline is a matter of familiar knowledge. Retardation in the growth of individual industries is to be expected in a world of scarce resources: not only is it ordinarily more difficult to double a large output of some commodity than a small one, but an increase in production at a uniform or increasing rate for a long period implies an aggregate prodigious beyond comprehension. In one way at least, the generalization of industrial retardation is little short of an arithmetic truism: nothing can compare with the percentage rate of growth of the initial output of an industry.[20]

1. Retardation as Characteristic of a Progressive Economy

We must seek, however, a more reasoned view of the causes of industrial retardation. Before attempting a detailed analysis, it is desirable to approach the problem from an a priori standpoint. Let us assume, then, that the total production of some economy is increasing at a uniform percentage rate over a period of sizable duration. Further, let us assume explicitly that this economy possesses certain progressive characteristics—many new industries are being started while some old industries are disappearing, labor-saving devices are being introduced, various economies are being effected in the utilization of raw materials, and so on. Since the ratio of manufactured output per unit of raw material consumed will be increasing, the aggregate output of raw materials

[20] The statistical records of several industries start almost at the stage of their commercial inception. If this were true of the bulk of the series analyzed, and if the retardation were confined to the early stage of development, the problem of retardation in industrial growth would be simple and unimportant.

will increase at a lower percentage rate than total production; but within the limits of this restriction, the aggregate output of raw materials may grow at a declining, constant, or increasing percentage rate. If the aggregate output of raw materials grow at a declining rate, the aggregate output of manufactures will also grow at a declining rate throughout, or else will at first grow at an increasing rate and later at a declining rate; while if the aggregate output of raw materials grow at a constant or increasing rate, the aggregate output of manufactures will grow throughout at a declining rate. If the aggregate output of raw materials increase at a declining rate, the rates of growth of individual raw materials will tend to decline more rapidly, even when their number remains fixed; [21] and they are virtually certain to decline more rapidly when their number increases, which is our original assumption. Similarly, if the aggregate output of raw materials increase at a constant rate, the tendency will be for the rates of growth of individual raw materials to decline. Finally, even if the aggregate output of raw materials increase at an increasing rate, the tendency will still be for the rates of growth of individual raw materials to decline,—provided there is a fair degree of divergence between the rates of growth of the raw materials, and their number increases at all rapidly. Similar relations hold between the rate of growth of the aggregate of manufactures and the rates of growth of individual manufactures. It follows, therefore, that the host of individual industries will grow at a declining rate, some of them declining absolutely. Some industries may, indeed, grow at an increasing rate for a considerable period, but they will form exceptions to the general rule. Within the limits of the assumptions which have been made, retardation in the growth of the generality

[21] See pp. 273–8.

of individual industries is an essential characteristic of a progressive industrial system.

It is important to observe that these assumptions hold with a reasonable degree of accuracy for the American economy during the period under survey. Industrial diversification and conservation in the use of raw materials are outstanding among the consequences of the technical progress characteristic of this period. The assumption of a uniform rate of growth probably does not conform exactly to what has actually happened, but it is practically certain that total production has not grown at a rapidly increasing rate, and only under the last condition, though not necessarily even then, would the above analysis be invalid.[22] It appears, then, that retardation in the growth of individual industries is linked to the sort of economic progress which the United States has experienced since the Civil War. And this view of retardation lends added significance to the statistical evidence already presented. It will be noticed that the frequency distribution of the rates of retardation (Chart 2) is skewed 'negatively', contrasting with the distributions of average rates of growth, presented in the preceding chapter (Chart 1), which are skewed 'positively'. Apparently, just as the forces making for growth of individual industries have dominated in the American system over the forces making for decline, so have the forces making for retardation in the growth of individual industries dominated in the system over the forces making for acceleration.[23]

The main thesis to be supported in the following pages is that retardation in the growth of individual industries is one of the expressions of the progressiveness of American industry.[24] With this end in view, we shall analyze succes-

[22] See Ch. VI, sec. III.

[23] See pp. 65–6.

[24] The suggestion may be ventured (see, however, p. 66, note 14) that increasing rates of growth (speaking algebraically) of individual industries are

sively the forces making for retardation which have been operative in the domestic markets for goods, the more fundamental forces which have been operative in the workshops of our national economy, the forces deriving from the impact of the outside economy, and the process whereby the various forces promoting retardation tend to cumulate in strength through their indirect effects. Next, we shall analyze the influence of structural changes on rates of industrial growth, and the forces making for different types of drift in the rates of growth of decadent industries. Finally, we shall attempt to interpret in general terms the variations in the actual rates of retardation of our statistical series.

2. Forces Operating in the Markets for Goods

In tracing the forces making for retardation which have been at work in the markets for goods, the major factors to be considered are technical progress, change in industrial organization, and population growth. We may start with population growth, probably the least important of these factors.

It is a familiar fact that the population of this country increased at a fairly uniform rate from about 1790 to 1860, but at a declining rate since then. In the current literature on production trends, reference is frequently made to the decrescent rate of population growth; and at times it is even argued that the declining rates of growth of various individual industries merely reflect the trend of population. This common theory doubtless contains an important element of truth; but it can scarcely be claimed with any seriousness that the trend of population can alone, or even largely, explain the abatement in the rates of growth of any

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probably characteristic of the late stage of a retrogressive economy. This, at any rate, is suggested by an analysis of retrogressive industries (see pp. 160–2). The point, of course, is mainly of academic interest.

considerable number of individual industries. If that were true, the trends of production of individual industries would resemble closely the trend of population. But as a matter of fact, the primary trends of industries, as expressed in their rates of growth and rates of retardation, differ very considerably among themselves, and few are of the same magnitude as population. Such statistics as are available suggest that most commodities have definite trends both in their consumption per capita and in their net foreign trade per capita.

However, any general influence of population growth on the trends of individual industries is obscured when they are considered separately, since the trends of individual industries reflect chiefly the variety of special influences impinging on them. It appears that the trend of the aggregate production of at least one important group of products, consumers' staples, has been dominated by the trend of population. All the indexes of production of principal crops trace out trends which resemble closely, especially since 1880, the trend of population, even though the trends of most of the individual crops do not. Such statistics on consumption as are available indicate that, while the dietary of the American population has changed considerably during the past few decades, the total food consumption [25] has varied rather closely with the increase of numbers. At most, a slight decline in the per-capita consumption of foodstuffs may have taken place.

The apparent domination of the trend of aggregate production of foodstuffs by the trend of population cannot,

25 See "The Decline in Per Capita Consumption of Flour in the United States" (Food Research Institute, *Wheat Studies*, Vol. II, No. 8, July, 1926); and O. E. Baker, "The Trend of Agricultural Production in North America and Its Relation to Europe and Asia" (contained in *Population*, giving the Lectures in 1929 on the Harris Foundation; University of Chicago Press, 1930), pp. 222–37.

however, be interpreted to mean that the latter has been an independent factor which has generated, so to speak, the former. The relation of population to production is one of interdependence. On the one hand, ignoring foreign trade, the size of population determines at any one time the aggregate production of consumers' staples. Even over a period of fair duration, the increase in the production of consumers' staples cannot be very different from the increase in population, provided the level of well-being in the economy is considerably above bare subsistence; for physiological laws set limits to the consumption of foodstuffs. In this sense, the declining rate of increase of population may be considered an 'ultimate' cause of the retardation which has taken place in the growth of production of foodstuffs. However, the size of population is itself closely related to the increase of national production. Our increasing material prosperity has tended to reduce the death rate, as it has promoted sanitation, medical knowledge, and medical care. The advance in material well-being has influenced also the trend of birth rates: it has improved the possibilities of increased parenthood and so has released forces working in that direction, but it has also made people more mindful of their improved standard of living and so has tended to promote limitation of the size of families (the indications are that the strength of the first influence has been declining and that of the second increasing). Finally, the advance in material prosperity has tended to stimulate migration: until very recent years, when rigid immigration bars were set up, the flow of migrants to this country varied directly, speaking broadly, with the state of national prosperity. Thus, the various factors back of the trend of population have been linked with the progress of our national industry, the decline in the rate of population growth being as deeply enmeshed in the industrial progress of the nation as the decline in the rates of growth of individual industries. For this reason, the fact that population has been growing at a declining rate is only of small help in explaining industrial retardation.

A more important factor is technical progress which has been incessantly operative in the American economy, releasing influences which have tended powerfully to retard the growth of individual industries. One of the ways in which technical progress has expressed itself is in the introduction of new goods. Our rising standards of living and increasing education have served as stimuli to industrial innovations, which have been carried forward rapidly by technical ingenuity, the advancing state of the arts, and venturesome business enterprise. Basic wants for food, clothing, transport, and recreation have come to be satisfied through an increasing number of media. The diversification of production has been most conspicuous in the case of elaborative manufactures, especially in the chemical industries; [26] but diversification has also extended to basic materials—beet sugar, bauxite, and natural gas are relatively new industries in this country. The new products have acted as substitutes for old, though the replacement of the latter has rarely been complete. With the increase of diversification, interindustrial competition has become more intense.[27] As every new product involves an absolute or relative shift of purchasing power from an old product, the increase in the number of goods has

[26] See *Chemical and Metallurgical Engineering*, January, 1931. This issue treats exhaustively of the problems of intercommodity and interprocess competition in the chemical industries.

[27] Of course, there are certain things that interindustrial competition, increasingly fostered by the growing variety of production, does not mean. For one, competition among goods is general and is not limited to the things which are directly substitutive—in the sense that they satisfy approximately the same specific want. Secondly, it is rarely true that an increasing number of directly competing goods have to share a fixed market or one growing at some natural rate.

tended to retard the growth in the production of old goods.[28]

The process whereby a new product diverts purchasing power to itself is generally as follows. A potential market of some size awaits almost every plausible commodity at its inception: there are always some people who clamor for novelties and are eager to seize any new opportunity to shift their outlays; and there are also others who habitually approach new commodities in a cautious but enterprisingly experimental spirit. So, new commodities which prove technically superior or satisfy important psychological wants are ready to march forward to success. As their production advances, they stimulate the industries with which they are technically (sequentially and complementarily) connected, while they encumber the industries to which they are competitively related. But the new industries themselves soon encounter resistance to a continuation of their earlier rates of development; for the custom of the more conservative members of the community, tied by inveterate practice or sentiment to old products, is gained only with increasing difficulty. Resistance from this side becomes greater with every fresh advance, except when a commodity becomes an object of competitive ostentation; though this too is self-limiting, for the wider the use of a commodity, the less does its possession become a mark of peculiar prestige. In part, the expanding production tends to overcome consumer resistance, for production on a quantity basis is conducive to various economies and improvements, which are reflected in

[28] The actual curve traced out by the production of any given industry is the net resultant of certain factors making for growth in production and others making for decline. Irrespective of the slope of the curve at any date, if a new force making for growth is added in the next date to the numerous forces impinging on the industry at the first date, the individual effect of this force will be to make for an increase in the rate of increase of the curve (that is, acceleration); and if the added force makes for decline, its individual effect will be to make for a decline in the rate of increase of the curve (that is, retardation).

falling prices. But, in the meantime, new commodities emerge: these come to exercise a restrictive influence on those which were only recently new: and the restrictive influence felt in any one industry is transmitted to the various industries which are technically related to it.

Industrial diversification has expressed itself not only in the production of an increasing number of commodities, but also in the production of given commodities by an increasing number of technical processes. Thus, wood pulp, a relatively recent product, is now the most important material in paper manufacture; aluminum-alloys have recently been added to the long list of structural materials; from the cottonseed now come many products obtained also in other ways; and the progress of chemistry has yielded synthetic camphor, indigo, resins, and still other synthetic products. An outstanding consequence of our technical progress is that given raw materials are being put to an increasing variety of uses. With the multiplication of technical methods for achieving given ends, industrial competition has tended to become intensified; for different technical methods generally involve the use of different materials, or the same materials in different proportions. As old commodities have been put to new uses, the rate of growth in the production of these commodities has tended to increase; but at the same time, the rate of growth in the production of the replaced commodities has tended to decline.

Practically every new commodity involves the use of new industrial equipment; and every substantial revision of industrial technique involves either a change in industrial equipment or the initial introduction of labor-saving devices. The substitution of machinery for hand-labor has tended to accelerate the progress of the machine-building, metal, and fuel industries; but labor-saving devices have often resulted in a saving of space, and so have tended to check the development of certain of the industries furnishing materials. Labor-saving devices and changes in the forms of industrial equipment have frequently made possible economies in the use of materials, and in this way have released forces making for retardation. Though various changes in the forms of industrial equipment have tended to stimulate the development of some industries, they have tended at the same time to restrict the development of others. For example, the increasing use of steel instead of wood in the construction of vessels has tended to retard the growth of the lumber industry. The increasing use of Diesel engines instead of steam engines has tended to retard the growth of the coal industry. The increasing replacement of farm work animals by automobiles and tractors has resulted in a rapid retardation in the production of horses and mules, has tended to retard the lumber industry, and has released millions of acres of crop land—which means that the increasing mechanization of agriculture has contributed to the retarded growth of certain of its branches, especially the production of oats and hay.[29]

Many revisions of technical processes are inspired primarily by the aim of, or incidentally result in, industrial conservation—using this term to indicate increased yield of raw materials in finished products, reclamation of used products, and recovery of waste products. The economic consequences of industrial conservation are similar, irrespective of whether they originate in new techniques for achieving given ends, in mechanical improvements of existing techniques, or in managerial improvements in the use of existing techniques.

[29] It has been estimated that 25 million acres of crop land were released between 1918 and 1930 on account of the automobile and tractor; this constitutes about 30 per cent of the acreage required for the sustenance of work animals at the earlier date. See O. E. Baker, "The Outlook for Land Utilization in the United States," *Journal of Farm Economics*, April, 1931, p. 214; and the same author's "The Trend of Agricultural Production," cited above, pp. 251–2.

When the ratio of manufactured output per unit of raw material consumed rises, or when used products are reclaimed, the demand for raw materials tends to decline; important forces are therefore released which make for retardation in the development of the industries producing raw materials. When the recovery of waste products takes the form of increased production of some commodity previously made, the aggregate output of that commodity tends to be accelerated; but its production by the older processes tends to be retarded, and this comes to be reflected in the production of the goods on which the older processes rest. When waste products are recovered and transformed into entirely new commodities,—the cottonseed products industry is rich in illustrations,—forces are set in motion which make for industrial retardation through the agencies of competition and substitution; this point has already been discussed and need not be further considered.

Industrial conservation has made tremendous headway in the United States. More effective utilization of raw materials has been rather general in industry. In animal husbandry, feeds have come to be converted with increasing efficiency into meat and milk; [30] and these economies have exercised a retarding influence on the production of feed crops and the various manufactured feeds. In the field of manufactures, improving ratios of output per unit of raw material used have been quite common: familiar examples are provided by the beet sugar, coke, head rice, and cottonseed industries. But perhaps the most remarkable instances of economies in the utilization of materials are afforded by the fuels, and some data are useful for illustrative purposes. In electric public utility power plants, 6.4 pounds of coal (or coal equivalent) were used in 1902 per kilowatt-hour generated, but only 1.68 pounds in 1929. In 1916, locomotives on Class

[30] See *ibid.*, pp. 261–6.

I steam railroads consumed 169 pounds of coal (or coal equivalent) per 1,000 gross ton-miles of freight service, and 18.5 pounds of coal per passenger-train car-mile; but in 1929 the corresponding consumption per unit of freight service was only 125 pounds, and per unit of passenger service 14.9 pounds. In the petroleum refining industry, the treatment of one barrel of crude oil required 860,000 B.t.u. in 1909, and 643,000 in 1928. In the cement industry, the consumption of coal (or coal equivalent) per barrel of output was 200 pounds in 1909, but only 158 pounds in 1928. In the iron and steel industry, 2.01 tons of coal (or coal equivalent) were used per ton of product in 1904, but only 1.41 tons in 1927. It has been estimated that the energy consumption per unit of output in the combined manufacturing and railway transportation industries declined as much as 33 per cent between 1909 and 1929.[31] It need hardly be stated that the remarkable advances in fuel efficiency have tended to retard the growth of the fuel industries, especially coal. Every improvement in industrial technique making possible a more effective utilization of a raw material has served to retard the growth in the production of that material.

The reclamation of used products has been practically as general as increasing yield of materials in finished products. The volume of 'secondary' production of many commodities has grown more rapidly than the volume of their 'primary' production. A few examples will indicate the increasing importance of 'secondary' production. Waste paper constituted in 1889 only 9 per cent of the weight of raw materials consumed in paper manufacture, but as much as 28 per cent in 1919, and 31 per cent in 1929. In 1909 the tonnage of scrap iron and steel consumed by steel works and rolling

[31] The figures are taken from F. G. Tryon and H. O. Rogers, "Statistical Studies of Progress in Fuel Efficiency," *Transactions of Second World Power Conference*, Berlin, 1930, Vol. VI; and from *Mineral Resources*. 1930, Part II, pp. 678–81.

mills was 52 per cent of the tonnage of pig iron consumed; the percentage rose to 61 in 1914, 67 in 1919, and 85 in 1929.[32] Between 1907 and 1929, refined lead produced from domestic ore increased at an average rate of 3.0 per cent per year, while secondary lead production increased at a rate of 11.0 per cent. During the same period, the smelter production of primary zinc increased at a rate of 3.7 per cent per year, but secondary zinc at a rate of 6.1 per cent; the smelter output of copper from domestic ore increased at a rate of 2.5 per cent, but secondary copper at a rate of 7.5 per cent. Between 1913 and 1929, the production of primary aluminum increased at a rate of 6.0 per cent, but secondary aluminum at a rate of 13.5 per cent.[33] Obviously enough, the relatively more rapid development of secondary than of virgin production in a number of industries has tended to retard the growth of the latter. Industrial reuse, then, has been an important factor in the declining rate of progress of many industries.

Technical progress—that is, mechanical innovations and betterments, and managerial improvements—has expressed itself in changes in the content and methods of production; and these changes have worked potently towards inducing retardation in the growth of individual industries. Along with the technical changes have gone changes in industrial organization, which have released myriad, though less powerful, influences making for retardation. An industry's organization comprises the geographic distribution of its producing units, their scale of operation, their interrelations of

32 The above figures are based on data in the *Census of Manufactures.*

33 In 1929 the ratio of secondary to primary output was .29 for zinc, .46 for copper, .40 for lead, and .43 for aluminum. While the figures of primary output entering into these ratios are for the smelter or refined products derived from both domestic and foreign ores, the trend computations (stated in the text) for primary copper and lead do not include metal of foreign origin. The sources of the data on primary production are stated in Appendix B, I; the data on secondary production are from *Mineral Resources.*

ownership and control, and their relation to the state. To the extent that industries have been relocated closer to the source of their raw materials, checks have become operative on the growth of transportation, and these have been transmitted to the metal, fuel, and allied industries. Similar consequences have ensued from horizontal combinations of the establishments of given industries. When the combination movement has taken the form of vertical integration, checks have become operative on the growth of trading. Insofar as enterprises have grown in size as a result of natural development, the consequences have frequently been the same as those arising from combination.[34] Industries founding trade associations have frequently been able to invade the markets and check the growth of competing industries functioning under a 'backward' form of organization. Finally, changes in the relation of given industries to the state have often released forces making for retardation.[35] These various types of change in industrial organization have operated incessantly during the period considered, and their influence on the rates of growth of individual industries has been considerable.

3. Forces Operating in the Workshops of the Economy

The introduction of new commodities, changes in the

[34] Changes in the scale of operation of the producing units of an industry, or in the ownership and control interrelations of these units, often lead to technical betterments; this factor, irrespective of its origin, has already been discussed.

[35] Of course, governmental action may tend to accelerate as well as retard the growth of given industries. In modern times the government has played a less obtrusive role in industrial affairs than formerly; but with the development of a philosophy of 'social control', the trend is now changing. The Prohibition Amendment is reminiscent of the general proscriptions of important industries practiced several centuries ago in various European countries. More frequently the government influences industrial trends by less drastic tools. The customary weapons are taxes, regulation of working conditions, regulation of business practices, and so on.

technical processes of making old commodities, and changes in industrial organization do not suffice to explain the generality of industrial retardation. For, if technical progress and change in industrial organization have released powerful influences making for retardation in the growth of some industries, they have at the same time released powerful influences making for acceleration in others. It remains to establish why the forces making for retardation have dominated in the generality of cases over the forces making for acceleration. To do this we must turn to the fundamental forces operating in the workshops of the economy. In the scarcity of productive resources we have a clue not only to the forces making for retardation operative in the workshops of the economy, but also to those operative in the markets for goods, for the latter originate largely in the necessity to conserve resources.

The introduction of new industries has tended to retard the development of old industries through the channels of competition for the factors of production, as well as through the channel of competition for custom. The flow of capital into new industries means an absolute or else a relative diversion of capital from other industries. Many new industries, a case in point is the airplane industry,[36] acquire abundant quantities of capital within a short period of their inception. The ability of a new industry to attract capital rests in large part on the expectation, at times actually realized as in the automobile and rayon industries,[37] that prodigious profits are to be made. A new industry may also divert capital to itself by promising stable rather than high

[36] See M. W. Watkins, "The Aviation Industry," *Journal of Political Economy*, February, 1931, pp. 57–60.

[37] See R. C. Epstein, *The Automobile Industry* (A. W. Shaw, 1928), Ch. IX; L. H. Seltzer, *A Financial History of the American Automobile Industry* (Houghton Mifflin, 1928); and M. H. Avram, *The Rayon Industry* (2d ed., London, 1930), Ch. V.

profits. For instance, the founding of the cotton manufacture in New Bedford created a safer outlet for investment funds than was provided by whaling and therefore led some of the wealthy citizens of the town to shift their funds from whaling.[38] The command by new industries over capital is not limited to the free capital (money) that they are able to attract; by bidding higher for the services of existing capital instruments, they are able to divert the uses of these instruments to themselves and in this way to acquire, in effect, command over the capital which these uses represent. The automobile industry furnishes a notable instance of a new industry which depended largely during its period of infancy on the capital facilities of other industries.[39] What is now chiefly important, however, is the fact and not the process of capital diversion. As capital flows into new industries, the quantity available for the old industries tends to be reduced, and this exercises a restrictive influence on their capacity for expansion. At the same time, the increase in the capital resources of the new industries enlarges the scale of their operations, lowers costs, and thereby strengthens their competitive power in the markets for intermediate and final goods.

One of the outlets of free capital is the labor market. In order to attract labor, new industries often have to outbid the older industries.[40] Thus, by offering high wages, the air-

38 W. S. Tower, *A History of the American Whale Fishery* (Publications of the University of Pennsylvania, Series in Political Economy and Public Law, No. 20), pp. 75–6.

39 The early automobile manufacturers did little more than assemble the parts furnished by wood- and metal-working enterprises, the 'bodies' furnished by carriage-makers, and so on. See Seltzer, *Financial History*, cited above, especially Ch. VI; also, his "The Mobility of Capital," *Quarterly Journal of Economics*, May, 1932.

40 New units of established industries also tend to bid higher for labor than old units. It is quite probable that the shift of labor from old to new industries and from old to new concerns within given industries has been important among the mechanisms through which a rise in the general level of wages

plane industry has been able to draw on the working forces of the automobile and furniture trades.[41] A more spectacular instance of diversion through the lure of high rewards is provided by the motion picture industry, whose personnel has been recruited in large part from the legitimate theatre. In order to attract a labor force, a new industry need not always offer a higher remuneration per unit of labor than the going rate for similar grades of work. It may offer instead earnings which are low on the average, but prodigious in exceptional cases. Thus, when gold was discovered in California, there was a rush of labor from all over the country to the gold fields, the whaling industry being among the chief sufferers.[42] Of course, the flow of labor into new industries may mean a relative rather than an absolute diversion of labor from old industries, and the former is of more frequent occurrence in a progressive country. In either event, as a new industry acquires command over increasing quantities of labor, its competitive strength in the markets for goods tends to improve, while the capacity of the older industries to expand tends to be restricted.

The new industries compete with the old also for supplies of various sorts, and ultimately, if not directly, for raw materials. The bidding by the new industries against the old industries will tend to effect a relative if not an absolute diversion of raw materials to the new industries. As the prices of raw materials rise, their production tends to be stimulated. But natural resources are scarce: lands of high fertility and rich ores of easy accessibility are available in

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has been brought about. The conspicuously high average level of wages in the western states is interesting in this connection. See P. F. Brissenden, *Earnings of Factory Workers, 1899 to 1927* (Bureau of the Census, Census Monographs, No. X), pp. 95, 138–42.

[41] M. Coleman, "Rank and File of the Air," *Survey Graphic*, October, 1928, p. 7.

[42] Tower, cited above, p. 74.

restricted quantities. As soils are worked more intensively and poorer lands come under the plough, increased expenditures of capital and labor are generally necessary to achieve given amounts of produce. And the resort to poorer mineral deposits means that the depth of mining must be increased, or ores of lower quality extracted, or more distant mines worked. In most branches of raw material production, technical advances have more than offset the tendency of natural resources to yield diminishing returns to applications of capital and labor; but in a few instances, as in anthracite mining and in whaling, diminishing returns have been for some time a thing of actual experience and not merely an operative tendency. The fact that technical improvements may counterbalance the increasing niggardliness of nature does not make the restrictive influence of natural resources any less significant. The retarding force is there, and tends to be diffused from the extractive branches of industry throughout the production system.

The insistence of the demand for industrial raw materials has involved, of course, the use of inferior resources. In many regions the quality of arable and pasture has deteriorated as a consequence of their being 'mined'. A good deal of the westward expansion of crop acreage in recent decades has meant a resort to lands of inferior quality, and consequently, lower yields. More conspicuous has been the resort to inferior mineral resources. The grade of dry and siliceous ore treated for gold has been declining for some years, as has the grade of siliceous ore treated for silver. The quality of copper ore has been worsening rapidly: before 1870 copper ores frequently yielded from 20 to 50 per cent in copper, but the average yield was only 2.50 per cent in 1906 and 1.41 per cent in 1928.[43] The yield of crude ores in the form of mercury

[43] F. E. Richter, "The Copper-Mining Industry in the United States, 1845–1925," *Quarterly Journal of Economics*, February, 1927, pp. 242–51; *Mineral*

has been declining persistently.[44] Though improved technology and new mineral discoveries have generally served to reduce 'real costs' more than inferior resources have served to increase them, the latter have prevailed in at least one mining industry of major importance, the anthracite coal industry, as may be gathered from the fact that the secular trend in the price of anthracite coal has been generally upward since the Civil War, and the secular trend in the productivity of anthracite miners downward since about 1900.

The competition for capital, labor, and materials has been viewed as taking place between new and old industries; and in this way it has become apparent how the continual accession of new industries comes to exercise a retarding influence on the older industries. But the competition for the factors of production is pervasive through industry: all industries, new and old, compete with one another for the use of productive resources, and the scarcity of these resources tends to exercise a restrictive influence on the growth of all industries. The retarding impulses are greatest when the available quantities of productive resources least admit of increase. As land area, considered with reference to both general and (at a given state of the arts) many special uses, is virtually fixed in quantity, the restrictive influence of its scarcity on the various land-using industries may be discerned with exceptional clearness. Thus, the decline of the lumbering industry is traceable chiefly to the pressure of the cropping and grazing industries. The decline of wool growing and the abated rate of progress of the sheep and beef-cattle industries are accounted for in large part by the encroachment of homesteading on pasture. The growing of

Resources, 1919, Part I, p. 556; *ibid.*, 1929, Part I, p. 546. Of the 12 major copper districts, 6 appear to have passed their zenith. See L. C. Graton, "Some Aspects of the Copper Industry," *Proceedings of the Mining and Metallurgical Society of America*, January, 1930, p. 11.

[44] *Mineral Resources*, 1925, Part I, p. 35; *ibid.*, 1927, Part I, pp. 62–3.

sugar cane has been checked by the fact that it is necessarily confined to the southern area and even in this region is grown beyond its natural climatic zone. And the rate of development of the corn industry has been checked by the difficulties of westward expansion, due to the semi-arid condition of the Great Plains, and of northward expansion, due to the shortness of the growing season.

However, the scarcity of productive resources is practically never absolute in any significant sense. Though it is at times convenient to speak of them quantitatively, their true economic meaning runs in terms of 'effectiveness' or 'productivity', which is a compound, most often inseparable, of their quantity and quality. More important than the size of the working population or the size of the land area under crops is the 'productivity' of the one and the other. The moral quality of a population enters significantly into the productivity of its labor, and the bounty with which its natural agents are endowed, into their productivity; but whether a given agricultural area or mine yields much or little to a given application of labor depends fundamentally on the technical competence with which labor is applied. Though the generosity of nature and the industrial qualities of the population may condition the state of technical knowledge, they are at any one time completely subordinate to it, for only through it can they be expressed. In this sense, the state of technical knowledge in a community is the chief 'cause' of its productivity. Every advance in technology means a decrease in the refractoriness of nature, an increase in the effectiveness of productive resources, and a decline in the scarcity of productive resources: it means, therefore, an increase in the possibilities of industrial growth.[45] The quan-

[45] Accurate appraisal of technical progress (viewed broadly, so as to include also improvements in the quality of labor and management), from an economic rather than an engineering standpoint, is most difficult. The available guides are given by price, 'net value product' per unit of output, and labor produc-

tities of the factors of production might remain fixed or even diminish; but if technical knowledge proceeded at a sufficiently rapid pace, the restrictions on the growth of industries arising from limited resources would be overcome; and the physical possibility would exist of continued growth, even at an undiminished pace, of the individual industries even of an economy whose pattern of production was becoming increasingly diversified.

But technical progress has served to reduce, not to eliminate, the restrictions of productive resources. As their influence remains, the extent to which a given industry can obtain a share of the available factors of production depends on its relative competitive power, which in turn rests in large part on its rate of technical progress in relation to other industries. Technical progress is Janus-faced: while improvements in any given industry, or in those technically related to it, always tend to stimulate its development, improvements in competing industries always tend to check its development. As variations take place in the technical progress of given industries in relation to their competing industries, changes tend to take place also in their relative competitive strengths in the markets for final goods and for productive factors. Thus, an old industry may be able to check the invasion of its markets by new industries if extraordinary improvements are effected in its technical methods. And a large technical improvement in an industry producing some raw material may enable it to reduce costs sufficiently to stimulate consumption even more than economies in the use of the material, originating in the technical improvements of

tivity. The first two are defective because of changes in the monetary factor; their meaning is further complicated when industries are wholly or partly monopolistic; finally, they reflect not only technical change but also 'diminishing returns'. Similarly, labor productivity measures the joint result of technical progress and refractoriness of nature. Further difficulties arise when the product is not uniform.

other industries, had served to reduce it.

Ordinarily, however, technical progress contributes more to the competitive power of the new than of the old industries, for technical progress is ordinarily more rapid in the early than in the late stages of the development of industries.[46] Technical progress tends to proceed at a declining rate because the possibilities of progress within any given industry are limited: the greater the improvements effected in an industry's technical basis, the less is left to be improved, and betterments tend, therefore, to decline in importance.[47] Thus, so far as progress in fuel efficiency is concerned, nothing can compare with the inventions made by Smeaton and Watt between 1769 and 1778; they reduced the coal consumption of atmospheric engines from 30 pounds per horsepower hour to 9 pounds, and therefore left a shorter road to travel than that already traversed.[48] Or take the influence of transportation methods on the 'real costs' of transporting: no matter how spectacular improvements in the future may be from an engineering standpoint, they can-

[46] This thesis has been argued brilliantly by Julius Wolf in his *Die Volkswirtschaft der Gegenwart und Zukunft* (Leipzig, 1912), Ch. VI. But it is to be observed that Wolf was concerned with the problem of retardation in general economic progress. To him, the 'law of limited technico-economic development' (das Gesetz der technisch-ökonomischen Entwicklungsgrenze) in individual industries was one of several 'laws' which pointed to a declining rate of general progress in the future. See below, Ch. VI, sec. III.

[47] The rate of mineral discoveries has characteristics similar to the rate of technical progress; and the two are, in a sense, substantially of the same significance, since the economic importance of each is expressed primarily in price. Every new mineral discovery reduces by so much the possibility of further discoveries, and for this reason a declining rate of mineral discoveries is to be expected. Apparently, the discovery of mineral deposits has actually been proceeding at a declining rate. There has not been an important discovery of iron ore in the United States since the Lake Superior ranges were opened up, a major lead discovery since 1886, a major gold discovery in twenty-five years. With the exception of oil, a major source of minerals has not been discovered in this country since 1910. See C. K. Leith, *World Minerals and World Politics* (McGraw-Hill, 1931), p. 26.

[48] See Tryon and Rogers, cited above, pp. 360–3.

not possibly reduce costs to the same absolute extent as did the steamboat and railway. Professor Kuznets found in his survey [49] of the technological histories of the cotton, woolen and worsted, iron and steel, boot and shoe, paper, and copper industries, that the rate of technical progress in each of these, except copper, has been slackening; and there are good grounds for questioning whether copper is any longer a real exception.[50]

It must be observed, however, that, restricting the point of view to something less than the entire histories of industries, the technical progress in a given industry tends to proceed at a declining rate only so long as the improvements effected do not alter the fundamental character of the industry's technique. Changes in the basic technological framework of an industry do take place occasionally—as in the glass industry during the last quarter of the nineteenth century with the coming of mechanization, in the rice industry during the decade of the 1880's with the adoption of implements employed in wheat-farming, in the Portland cement industry around 1890 with the introduction of the rotary kiln, and in the sulphur industry around 1900 with the application of the new Frasch process. In such cases, it will generally be found that the rate of technical progress has abated definitely in the period subsequent to the date when the fundamental transforming 'invention' took place; though

49 Kuznets regards the tendency towards abatement in the rates of technical progress in individual industries as the most important cause of retardation in their growth. See his *Secular Movements*, cited above, Ch. I.

50 According to F. S. Butler, "there is indubitably a law of diminishing returns applying to further technologic advances in copper production, because the aggregate losses in its treatment have become relatively slight and the maximum benefits of large tonnage production are probably already generally realized in mining, milling, and smelting practice" (*Mineral Resources*, 1928, Part I, p. 713). Professor L. C. Graton expresses (in a letter to the writer) assent to the above statement, except that he would prefer to say that "there is a tendency toward diminishing returns applying to further technologic advances . . . . etc."

when the period of observation is extended back of that date, the length of the period encompassed will alone determine whether the rate of technical progress may be considered as having abated. It is true, then, that old industries may experience technical changes comparable in magnitude with those ordinarily experienced by new industries; but the important fact is that revolutionary changes in the technologies of industries are rare—centuries elapsed between the invention of the mariners' compass and the steamboat. The basic technological framework of most industries has remained the same since the 'industrial revolution' took place in them; and in view of the persistence of the basic framework of industries, the generalization that technical progress tends to abate as the age of an industry increases is, in practice, no less significant for its being restricted to the period within which that framework continues.[51]

Though old industries are able to replenish their vigor from technology, they are generally unable to do this sufficiently to offset the check to their rates of development, which comes from the more rapid technical progress of competing new industries. Being special beneficiaries of technical progress, new industries tend to reduce the prices of their products more than old industries, and therefore tend generally to increase the markets for their products more rapidly. Apart from the stimulus derived from falling prices, the markets for new products tend to grow swiftly for a time because of the customary receptivity of some buyers to new products. The general result is that the old industries find the markets for their products dwindling relatively if not

[51] It may be argued that when the basic technological framework changes, what we really have is a cessation of one and the inception of another industry. Wolf's generalization becomes almost universally true on the basis of such a conception of industry. However, were it not for the fact that the basic technological framework of industries changes very infrequently, Wolf's generalization would be of little importance.

absolutely; and when they attempt to recapture their markets by cutting prices, in the expectation that they may be able to transfer the burden to the factors of production, they find themselves foiled by the new industries which, favored by expanding markets and inflow of capital, are bidding up the prices of productive agents. What is true of 'old' industries soon becomes true of the 'new'; for in the very periods of their adolescence, they are already obstructed by younger and more vigorous industries.

Thus, as the American economy has progressed, abatement has been experienced in the rates of development of its individual industries. The declining rate of population growth has been, if at all, an 'ultimate' cause of the retarded growth of only the aggregate production of foodstuffs and certain other consumers' staples. More important factors are industrial diversification and industrial conservation, operating in a world of scarce productive resources; and the tendency of technical progress, of whatever sort, to take place in individual industries at a diminishing rate. The number of commodities produced has been increasing rapidly in the face of scarce resources; and although improvements in our many-sided technology have served to diminish the restrictions imposed by scarce resources, they have not sufficed to permit the growing number of individual industries to advance at an undiminished rate. Industrial conservation has made extensive headway and has potently promoted retardation in the industries producing raw materials; and while industrial conservation, like other forms of technical progress, has served to increase the extent to which productive resources will go, it has not done this sufficiently to enable individual industries, including the raw materials or even excluding them, to advance at an undiminished rate in the face of increasing industrial diversification. Finally, the rate of progress in the technical processes of our individual industries, whose number has been steadily increasing, has been uneven: it has been more rapid in the new than in the old industries, and it has therefore made for a more rapid rate of growth in the new than in the old industries and for a more rapid rate of growth in the early than in the late stage of given industries.

4. Impact of the Outside Economy

The forces making for retardation have operated unceasingly, but without regard to political boundary lines. They have been operative in the markets and workshops of the outside economy as well as in our own: new mineral discoveries, new branches of manufacture, changes in industrial organization, and new or improved industrial techniques in foreign countries have influenced the production trends of our industries in much the same way as have economic changes in this country. Those of our industries which produce commodities that move in foreign trade are branches of world industries, and are therefore immediately affected by any changes in the outside economy; and those of our industries which produce solely for the domestic market are related by commercial and technical bonds to those producing partly or wholly for the foreign market, so that the influences exerted on the latter tend to be transmitted to the former. The foreign branch of a world industry may experience growth because of improvements in its technology, general industrial environment, or organization (particularly, its relation to the state, as expressed in tariffs, bounties, and so on); but irrespective of what the causes making for the growth of the foreign industry may be, they will exercise a retarding influence on the domestic industry, and this influence will tend to be reflected in the industries related to it. Similarly, the forces making for a decline in the foreign branch of a world industry, provided they arise out of the internal economy of the industry rather than its industrial environment, will exercise an accelerative influence on the domestic industry.

While the impact of the outside economy on domestic production cannot be measured statistically, it can be detected roughly in statistics of the changing contribution of the United States to the world output of various commodities. Such data might be presented for a fairly large number of commodities; but this is unnecessary, and the few figures in Table 26 will suffice for illustrative purposes. The table records the percentage of the world production of certain important materials which has been accounted for by the output of the United States, by decades from 1870 to 1910, and quinquennia since then. These percentages are crisp summaries of the effects of the myriad factors impinging on the development of the American and foreign branches of certain world industries. When the forces making for the growth of an industry producing an 'international' commodity are more potent in the outside economy, the domestic percentage of the world output will decline, and the converse will hold when progressive forces are more potent in the domestic economy. Table 26 is limited to commodities in the production of practically all of which the United States has had of late, if not for some time, a declining share in the world total; but the table is not intended to convey, and it would be wildly inept if it did, any inferences concerning the trend of American production as a whole in relation to world production.

Bearing in mind the limited scope of the data and their illustrative function, they are amply illuminating; for they indicate that the development of the outside economy has been an important force making for a declining rate of growth of many domestic industries. The commodities listed in Table 26 fall into three groups. First, come gold, silver,

Table 26

PERCENTAGE OF WORLD PRODUCTION OF CERTAIN RAW MATERIALS ACCOUNTED FOR BY DOMESTIC PRODUCTION*

Period	Gold	Silver	Cotton	Wheat	Petroleum	Coal	Pig iron	Steel	Copper	Lead	Zinc
1870–1879	37.4	41.5	73.9	21.3	86.8	18.0	15.5	20.7	14.8	14.8	7.3
1880–1889	31.2	42.4	79.7	22.5	66.7	25.3	23.7	30.2	32.9	26.2	12.8
1890–1899	23.8	35.9	68.4	24.5	51.8	29.3	31.5	36.0	51.2	23.1	20.0
1900–1909	24.0	31.3	66.4	21.5	56.2	35.9	40.0	42.6	56.0	28.8	27.4
1910–1914	20.6	30.2	66.1	19.6	64.2	38.6	39.8	41.6	56.3	32.9	31.8
1915–1919	19.4	37.4	63.5	23.4	67.4	43.0	55.6	54.3	60.6	43.7	59.7
1920–1924	14.6	29.2	60.7	23.3	67.2	40.7	52.8	53.4	52.7	40.2	48.1
1925–1929	11.7	24.3	62.1	19.1	69.6	37.9	45.8	48.4	50.6	35.8	41.7

*SOURCES: These figures are based on data from a variety of sources, of which only the more important will be indicated. (A) World production figures: gold and silver—*Annual Report of the Director of the Mint*, 1930, p. 263; cotton—Latham, Alexander & Company, *Cotton Movement and Fluctuations* (20th ed.), p. 147, and the Department of Agriculture (see *Yearbook of Agriculture*, 1931, p. 562, for graph); wheat—*Cincinnati Price Current*, April 18, 1901, p. 251, and Food Research Institute, *Wheat Studies*, April, 1933, p. 264 (the figures of the *Cincinnati Price Current* were adjusted to the level of the figures in *Wheat Studies* on the basis of the overlap for 1885–90); petroleum—*Mineral Resources*, 1929, Part II, p. 471; coal—American Iron and Steel Association, *Annual Report*, 1911, Part II, p. 63, and *Mineral Resources*, 1929, Part II, p. 801; pig iron and steel—M. Meisner, *Die Versorgung der Weltwirtschaft mit Bergwerkserzeugnissen*, Vol. I, 1860–1926, Part II, pp. 84 and 86, and Verein deutscher Eisenhüttenleute, *Gemeinfassliche Darstellung des Eisenhüttenwesens*, 9th, 12th, and 13th ed.; copper—Bureau of Mines, *Economic Paper 1*, pp. 3, 5; lead—Bureau of Mines, *Economic Paper 5*, p. 5; zinc—Bureau of Mines, *Economic Paper 2*, p. 5. (B) Domestic production figures: The series used are those given in Appendix A, Table 44, and described in Appendix B, except for cotton, its source being the *Yearbook of Agriculture*, 1931, p. 672. (The series 'lead, domestic' was used for lead.)

COMMENTS: The figures in the table give calculations from sources which are often inexact, and the single decimal is no indication of the order of accuracy. In the case of zinc, the figures for 1870–79 refer to 1871–79 only; copper, 1871–80; and wheat, 1873–79. The figures for copper for 1880–89 refer to 1881–90. The figures for cotton for 1890–99 refer to 1891–99. The coal production figures include lignite. China is explicitly excluded from the figures on world production of cotton for the years from 1891 on; China and southwestern Asia are explicitly excluded from the figures on world production of wheat from 1885 on.

cotton, and wheat; these commodities are of the type in which America's relative contribution to the world total has been declining fairly persistently for a rather long period.[52] Petroleum stands by itself; the American percentage declined for some years, but it has risen of late, and during the last decade the percentage was higher than during any other except the first. The remaining commodities are mineral products of major importance—coal, pig iron, steel, copper, zinc, and lead. They tell an astonishingly uniform story: for some time their production forged ahead more rapidly in the United States than in the rest of the world; a peak was reached during the War period; and since then the outside economy has definitely outstripped the United States. The American output of these mineral products increased disproportionately during the period of War stress, so that a relative decline was to be expected once Europe's productive capacity was restored. However, the drift of the percentages for certain of the commodities, most notably copper, suggests that the War merely accentuated a peak which was already impending.

The impact of the development of the outside economy on the fortunes of individual industries in the American economy may also be detected in figures of the fraction of the domestic output of various commodities which has been exported. Such statistics are not nearly so informative as the data already presented: the relative exports of a commodity may be constant while the relative contribution of the domestic product to the world total is declining, for domestic production may grow at the same rate as domestic consumption but at a lower rate than world production: or the relative export of a commodity may be declining while the relative contribution of the domestic product to the world

[52] Except for wheat, which rose during the War and immediate post-War years.

total is increasing, for the domestic economy may be outstripping the foreign economy in both production and consumption, but to a greater extent in the latter. All the same, the figures in Table 27, restricted to agricultural staples of large contemporary interest, are of some significance; for they strengthen the common impression that the competitive power of American agriculture in world markets has been declining for some time. It will be noticed that the trend in

Table 27

PERCENTAGE OF DOMESTIC PRODUCTION OF CERTAIN AGRICULTURAL PRODUCTS EXPORTED *

Period	Corn	Cottton	Tobacco	All meats	Wheat	Oats	Barley
1870–1879	4.6	69.3	69.5	...	21.3	0.5	2.5
1880–1889	3.5	67.1	47.2	...	24.7	0.6	1.5
1890–1899	5.7	67.4	48.9	...	26.6	3.0	8.4
1900–1909	3.1	64.4	38.0	10.8	21.0	1.4	5.6
1910–1919	1.4	52.5	33.8	9.7	22.9	4.8	10.6
1920–1929	1.8	50.5	33.7	7.4	23.6	1.3	14.7

* SOURCES: (A) Production figures: The data used are those given in Appendix A, Table 44, and described in Appendix B. The figures for 'all meats' are taken from Department of Agriculture, *Statistics of Meat Production, Consumption and Foreign Trade of the United States*, 1900–1930 (mimeographed). (B) Figures of exports: The data are taken from *Yearbook of Agriculture*, except for meats, their source being *Statistics of Meat Production.*

COMMENTS: Figures of exports relate to 'net exports'; this includes total exports (domestic plus foreign) minus total imports. In 'all meats' are included beef, veal, lamb, mutton, pork, and lard. There are no data for meats prior to 1900.

relative exports has been sharply downward in cotton and tobacco, the two major crops of which the largest percentage of the domestic output is exported; that the trend has been definitely downward in corn, and meat products; slightly downward in wheat; [53] and upward, though sharply so, in barley only. Various statistics indicate that the proportion of

[53] According to the figures of the Department of Agriculture, the trend in the relative export of wheat has been pronouncedly downward. The wheat production figures used in Table 27 are estimates of the Food Research Institute.

our aggregate agricultural output exported has been declining decisively,[54] and that even the general trend of the volume of agricultural exports has of late been downward. For a time the War afforded a buoyant interlude to agricultural exports, but there has been little else to check their decline. In part, the decline is accounted for by increasing domestic consumption, but the competitive advantage of certain new agricultural areas in foreign countries has been an important contributory factor.[55] The decline in agricultural exports has tended to restrict the rate of growth in the production of agricultural staples in this country.

5. Cumulation of Retardation Forces

Though we are concerned in this inquiry with the causes of industrial retardation, not with its consequences, certain of the effects of retardation are important in promoting further retardation, and account must therefore be taken of them. Once a decline in the rate of growth has become marked, it is rarely accepted fatalistically by an industry. The leading firms will strenuously set about to improve their product, acquaint the public with its merits, or extend its possible uses. Such activities being in the interest of the industry as a whole, they are best pursued in concert through some central agency. Thus, retardation of industrial growth promotes industrial consciousness, perhaps more so than any other factor; and when a feeling of common interest has be-

[54] Beginning with 1895, the decade rates of the series 'agricultural exports' (a rather comprehensive index of the physical volume of agricultural exports) are consistently below, except for 1910–20, the decade rates of any of the indexes of production of major crops. Also, the retardation indicated by agricultural exports is −1.3 per cent, while the various crop indexes show a retardation of about −0.8 per cent. The coverage of the indexes of crop production is not the same as of the index of agricultural exports, but the difference between their rates of growth would probably be larger if the indexes of crop production had as large a coverage as the index of agricultural exports. See pp. 264–5.

[55] See pp. 68–9.

come sufficiently crystallized, it is often given concrete form in a national trade association. The main object of such a body is to promote the group interest; that is, to aid its members in obtaining the largest possible fraction of the total national income.

Technical research is one weapon employed by an industry experiencing a declining rate of growth. It is conducted, in part, cooperatively through a trade association binding the enterprises of the industry together,[56] and in part, individually by the strategic establishments of the industry. The general aims of technical research are to lower costs, improve the industry's product and the products complementary to it, and develop new uses for the product. But technical research, especially when conducted by private enterprises, is often inspired by a still higher aim: the development of new commodities which may prove marketable, attain considerable vogue, and become industrial prodigies. Systematic industrial research is a powerful weapon [57] of industrial defense and offense: in the degree to which it is wielded successfully by an industry, old markets are regained and new markets won.

The fundamental objective of any industry is to maintain and extend its markets. At least over short periods of time, this objective may be realized with considerable success, even when the product of the industry is technically defective. Technical betterments themselves are sought primarily for the gains they may bring in the markets for goods. Hence, an industry experiencing retardation is even more likely to resort to increased selling activity than to technical research; and when it does resort to the latter, it will almost always also resort to the former. There is a strong tendency for the

[56] See *Cooperative Industrial Research* (U. S. Chamber of Commerce, Department of Manufacture, Publication No. 1019).

[57] See T. M. Switz, "An Economic Appraisal of Intercommodity Competition," *Chemical and Metallurgical Engineering*, January, 1931.

trade association of such an industry to become active in the promotion of sales: to conduct market analyses with the aim of discovering latent sources of purchasing power; engage in publicity campaigns intended to acquaint the public with neglected merits of its product; bring its product before the public through the medium of symbolic advertising; attempt to stimulate legislation calculated to prove beneficial to the industry, or else detrimental to competing industries; and try to foster 'friendly relations' with the general public —especially when there is any danger of governmental interference with the wonted course of the industry. Quite apart from the efforts expended by the trade association, the strategic firms persistently pursue sales activities on their own account: they advertise, publicize, and devise ingenious schemes of financing and service. In a variety of ways, then, the sum of salesmanship is fostered. Instances of striking originality in the technique of salesmanship are to be found in all kinds of industries, but they are most likely to be found in hard-pressed industries fighting for their very existence. And perseverance and ingenuity in marketing are frequently rewarded by new markets.

Industries as yet undisturbed by retardation will often wield technical research and salesmanship, the two weapons of interindustrial competition, quite as militantly as industries experiencing sharp retardation; for they will attack today in order to be better able to defend tomorrow. The numerous industries wielding these weapons have done so with varying diligence and proficiency, and success has been unevenly distributed. Taken as a whole, the conquests to be imputed to them are very large, and much of our industrial history would be different were it not for their operation. But only this is now important: the industries which succeed in maintaining or extending their markets, through the pursuit of technical research and large-scale salesmanship, intensify by the very fact of their success the difficulties of other industries. As technical research and salesmanship are cultivated more intensively, the tempo of industrial change is increased. Every technical betterment or marketing gesture releases fresh forces making for retardation in the growth of individual industries. So, the forces making for retardation, earlier analyzed, are seen to cumulate in strength; once released, they are not soon spent, but rather gain momentum as they work themselves out through some of their effects.

6. Influence of Structural Changes

We have argued that the forces making for retardation in the industries of an advancing economy tend to dominate, in the generality of cases, over the forces making for acceleration. Except for casual mention that abrupt and revolutionary changes occasionally take place in the technologies of industries, the argument has implicitly assumed that economic changes operate in a continuous and regular way—that is to say, that their impact on a given industry at any one date is closely correlated with their impact at any preceding date. This is doubtless the case in the generality of individual industries; were it otherwise, production records would ordinarily show 'breaks' and 'discontinuities'. However, such 'breaks', though rare, are found occasionally: they may be caused by a comprehensive transformation of an industry's technology,[58] a new invention which revolutionizes the market for an old industry's product, a discovery of a mineral deposit overshadowing known deposits, or a revolution in fashion. When some such cause impinges on an industry, one epoch in its history has really come to a close and another begun. A single trend line fitted to portions of both epochs is likely to be misleading. It may show an in-

[58] See pp. 142–3.

creasing rate of growth; but when the acceleration is traceable to a discrete, fundamental change in the conditions underlying the industry's operation, it cannot be interpreted as a reflection of continuously operating forces. Such a trend line may conceal the decline in the rate of growth up to the time when the revolutionizing change took place, and also the retardation subsequent to that change. A number of the instances of acceleration which our statistical survey has disclosed—rubber imports, light petroleum distillates, burning oils, cigarettes, and face brick—are of just this character.

Thus, the growth of the automobile industry revolutionized the demand for the products of the rubber, and petroleum refining industries. Previous to 1910 or thereabouts, the growth of rubber imports reflected the manufacture of such things as boots and shoes, raincoats, and medical supplies; but since 1910 rubber imports have been increasingly dominated by the demand coming from manufacturers of automobile tires, casings, and tubes.[59] Similarly, prior to about 1910, products of the petroleum refining industry found their chief uses as illuminants and lubricants; since then, gasoline—the driving fuel of the internal combustion engine—has become the most important product of petroleum refining. The output of other derivatives of crude petroleum has also increased rapidly, though as a consequence very largely of their joint production with gasoline. It is true enough that the rubber and petroleum refining industries show acceleration in our measurements, but the period since 1870 has not been 'homogeneous' for these industries, and when it is broken down into economic subperiods, the rule of retardation is actually found to hold. The data of rubber imports show a break in trend some time

[59] See R. B. Prescott, *Analysis and Forecast of the World's Crude Rubber Consumption* (pamphlet by Rubber Association of America, May, 1924), pp. 9–10.

around 1910—more particularly, a declining rate of growth up to about 1910, and a declining rate of growth once more, though along a steeper trend, since then. Data on the production of light petroleum distillates [60] tell almost exactly the same story; and so do the data on burning oils, but not with quite the same distinctness.[61]

Other industries whose underlying conditions changed radically at some time during the period under survey are cigarette production and face brick production. A new stimulus of large magnitude was imparted to the cigarette industry during the War, when the cigarette became the smoking favorite of soldiers, and this stimulus has been carried forward by the widespread adoption of the cigarette by women. Despite the acceleration indicated for the period taken as a whole, the period up to about 1915 shows distinct retardation, and so does the period since that date.[62] In the face brick industry, a strenuous advertising campaign has apparently resulted in lifting the level of output of the industry in the period since 1920. Again, despite the acceleration indicated for the period as a whole, the period up to about 1920 shows retardation, as does the period since then, though along a much steeper trend than previously.[63]

[60] This series includes more than the production of gasoline; see Appendix B, II. But if a record of gasoline production alone were available, it would probably have the same trend characteristics.

[61] Rubber imports show an acceleration of 1.6 per cent for the period 1870–1929, but a retardation of –0.5 per cent for 1870–1910. Light petroleum distillates show an acceleration of 3.1 per cent for 1879–1929, but a retardation of –0.7 per cent for 1879–1909. Burning oils show acceleration not only for the period 1879–1929 but also for 1879–1909; but the gaps in data for the early period are greater than for the later period, and the relations of the figures for 1879, 1889, 1904 and 1909 appear somewhat irregular. Each of the three series shows unmistakable retardation for the period since 1910; this period is too short to warrant the computing of retardation measures.

[62] Cigarette production shows an acceleration of 0.3 per cent for the period 1880–1929, but a retardation of –1.1 per cent for 1880–1915. It is to be observed, however, that there is no very definite 'break' in the trend of this industry at 1915 or thereabouts. See p. 119, note.

[63] Face brick production shows an acceleration of 0.5 per cent for the period

Fundamental changes in the conditions of industrial operation have not been limited to industries in the group evidencing acceleration. It is partly an accident of the periods covered that our measures show declining rates of growth for certain of the other industries affected by revolutionary changes—particularly petroleum, rice, and sulphur. It has already been observed that beginning with about 1910, the automobile provided a great stimulus to the rubber and petroleum refining industries. The technical conditions of extracting petroleum permitted a large expansion in these industries. So, while petroleum production evidences moderate retardation for the period 1870–1929, it shows considerably greater retardation for the period 1870–1910.[64]

The sulphur industry is instructive because it furnishes an instance of a 'break' in trend originating in a technical invention which made tremendous deposits of a coveted mineral commercially available. Prior to about 1900 the American sulphur industry was of negligible importance, most of the sulphur used in the country coming from Sicily. Though extensive and pure sulphur deposits were known to exist in Louisiana, they could not be mined in the ordinary way, as they were overlain with quicksand impregnated with hydrogen sulphide gas. In 1901 mining was started through a method, invented by Herman Frasch, whereby sulphur was melted underground and then pumped to the surface.[65] With the leading technical problem solved, the production of sul-

1879–1929, but a retardation of –1.5 per cent for 1879–1920. The retardation would not be quite so high for the latter period were the War-years excluded.

[64] The measure of retardation is –0.3 per cent for the period 1870–1929, but –0.9 per cent for 1870–1910. (However, the 'break' in the trend of petroleum seems to come somewhat earlier than 1910.) Petroleum production does not show any retardation since 1910.

[65] H. Wigglesworth, "Chemical Industries" (Ch. IV in *Representative Industries in the United States*, ed. by H. T. Warshow; Henry Holt, 1928), pp. 135–6. The Louisiana deposits have since been exhausted, mining operations having been suspended in 1924. But large deposits have been found in Texas, and the industry has continued to grow.

phur began to mount: it rose from 5,000 tons in 1902 to 85,000 tons in 1904 and to 364,000 tons in 1908; by 1917 output exceeded one million tons, and in 1929 it reached the stupendous aggregate of 2,362,000 tons. While sulphur production shows a declining rate of growth for the period 1880–1929, its rate of retardation for the period since 1900 is very much greater.[66]

Finally, the rice industry provides an instance of a break in trend originating in mechanization. Though the American rice industry dates back to colonial days, its present mechanized technique goes back to only about 1890. The transformation in the technology of this agricultural industry was carried through in very short time. During 1884 and 1885 the Louisiana prairies were settled by a group of farmers from the northwestern prairie states. Some one among them conceived the brilliant idea of transferring the implements employed in wheat farming to rice cultivation. "In place of the old hand-sowing, hand-hoeing, and hand-harvesting, now came the gang-plow, the broadcast-seeder and drill, and disc harrow, and the twine-binder and harvester." [67] A sharp break in the trend of rice production can be discerned during the decade of the 'nineties. While rice production is credited with only a mild rate of retardation in our measures, the actual rate of retardation was rather considerable during the economic subperiods bounded approximately by the year 1895.[68]

The instances of abrupt change in the conditions of industrial operation which have been cited indicate that the assumption of continuity in economic change, on which our

[66] The measure of retardation is –2.3 per cent for the period 1880–1929, and –7.5 per cent for 1900–29.

[67] A. H. Cole, "The American Rice-Growing Industry: A Study of Comparative Advantages," *Quarterly Journal of Economics*, August, 1927, p. 605.

[68] The measure of retardation is –0.4 per cent for the period 1870–1929, but –3.5 per cent for 1870–95 and –5.5 per cent for 1895–1929.

general analysis of the causes of industrial retardation has mainly proceeded, does not conform to the actual events in the histories of some of the industries; but the instances of discrete change indicate no more than this. A vitalizing force of large magnitude occasionally impinges on an industry and quickly transforms its status in the economic system. When a fundamental change in the underlying conditions of an industry takes place within a short period, a 'break' in its trend will generally be discernible. A measure of retardation encompassing portions of the period preceding and following the fundamental change will understate the true retardation, and at times will show even acceleration.[69] But the rule of retardation seems to hold when industrially homogeneous subperiods are analyzed separately.

7. Retardation and Industrial Decadence

For a time the forces making for retardation may be more than offset or just offset by those making for acceleration. But in a progressive economy the forces conducing to retardation operate with great effectiveness: many industries soon find that not only has their growth been retarded, but that it has been retarded so extensively that they have actually entered the phase of decadence. In some cases the forces making for retardation continue to press relentlessly until the industry reaches extinction. In other cases, the forces making for retardation relent: an industry may continue to shrink, but at a declining rate, or it may even experience a favorable structural change and become revitalized; such industries will show an increasing rate of growth in an algebraic sense.

[69] We have considered only such breaks in trend as mark industrial revitalization, this being the one type revealed by our series. A case of sudden collapse is afforded by the mackerel industry, which experienced an almost perpendicular decline in output during the middle 'eighties. See *Outlook for the Mackerel Fishery in 1931* (Bureau of Fisheries, Fishery Circular No. 4), p. 4.

The drift in the rates of decline of decadent industries is in some ways more puzzling than the drift in the rates of growth of progressive industries. It is therefore regrettable that the available statistical record of decadent industries is seriously inadequate. Viewed from the standpoint of both the duration and the intensity of their decline, only the following of our series show pronounced decadence: cod and mackerel, whale, hemp, New York canals traffic, maple sugar, walking plows, non-Portland cements, and mercury. With a view to obtaining a larger grasp of decadent industries, we may add several series hitherto unanalyzed—iron rails, anthracite pig iron, charcoal pig iron, cut nails, and fine cut tobacco.[70] Even so, the number of decadent industries remains small; but since the data available do not enable us to go further, they will have to serve our purpose.

Two groups or types of decadent industries raise no new questions. The first comprises industries which have vanished completely—such as iron rails and anthracite pig iron.[71] The forces making for retardation have pressed insistently in such industries, not relenting until the industries disappeared. Necessarily, their rates of decline increased rapidly, at least during the last phase of retrogression. The second group comprises 'decadent' industries whose decline has been checked as a result of some structural change. A case in point is New York canals traffic which has experienced a notable revival since 1918, when the elaborate canal improvements, under way for many years, reached completion. If we confine our observation of New York canals traffic to the period prior to about 1920, a very considerable retardation is evi-

[70] Figures on the production of fine cut tobacco are given in the *Annual Reports of the Commissioner of Internal Revenue.* Figures for the other supplementary series are given in the *Annual Statistical Reports of the American Iron and Steel Institute.*

[71] Iron rails have not been produced since 1911. No pig iron has been smelted with anthracite alone since 1914, and none with an anthracite-coke mixture since 1923.

denced, even though the full period through 1929 shows acceleration in our measures.[72] There is little difference between this instance of industrial rejuvenation and those cited earlier.

The case of decadent industries which are still with us and whose decline has not been interrupted by a structural change is more difficult to comprehend. The statistical records we have for industries of this type suggest that once their trend has turned definitely downward, the rate of decline increases for some time, but later begins to abate. The duration of the period over which the decline is accelerative varies from industry to industry. It appears to have been rather brief in the production of non-Portland cements and cut nails, but rather long in the whale 'fishery'. In certain industries—for example, the production of hemp, mercury, charcoal pig iron, maple sugar, fine cut tobacco, and walking plows—the phase of abatement in the rate of decline does not appear to have been reached even yet; and there is no telling whether it ever will be. Those decadent industries which have entered the phase of abatement in their rate of decline are very likely to show acceleration in our measurements.

The fundamental question which decadent industries raise is why some of them show abatement in their rates of decline after a certain period of decadence. The fact of abatement means that the resistance offered by the declining industry to further inroads on its markets increases. The smaller the output of a declining industry, the greater is such resistance likely to be; for, with a small output, the industry comes to satisfy fairly tenacious and impregnable wants. The decadent industry may produce an altogether inferior product; but the ignorance or inertia of small

[72] An acceleration of 0.8 per cent is indicated for the period 1870–1929, but a retardation of −1.6 per cent for 1870–1920.

groups may enable the industry to linger on. Or else a declining industry may produce a commodity, which has, or is believed to have, special merits for certain uses; and as the amount required in these residual uses approaches more closely the total consumption of the commodity, the rate of decline of the industry will tend to abate. Thus, the cut nail has been increasingly supplanted by the wire nail, which is easier to handle, more attractive in appearance, and for which automatic nailing machines have been devised. But the use of cut nails has continued in hardwood flooring and paneling, in part because blunt-pointed nails tend to prevent splitting, and in part because there is a belief in the trade (not wholly justified) that cut nails have greater holding power. About 90 per cent of the current output of cut nails goes into flooring and paneling; and the persistence of the demand for these uses has checked the rate of decline of the cut nail industry.[73]

Then again, if the demand for one of a group of commodities produced by a joint process is sharply curtailed, the continuing demand for another of the joint products may tend to check the rate of the industry's decline. Such abatement in the rate of decline may take place even in the face of rapidly diminishing resources. Thus, the American whaling industry suffered a severe setback when whale oil and sperm oil gave way to kerosene and paraffin wax; and even the persisting demand for whalebone did not suffice to check the rate of decline.[74] When, some time later, the demand for whalebone was practically eliminated as a consequence of change in dress fashions and of the development of substitutes for the costly whalebone, the whaling industry was operating at a very low level, and only a small stimulus

[73] The writer is indebted for information concerning cut nails to Mr. R. W. Thompson of the Reading Iron Company and Mr. J. A. Newlin of the Forest Service of the Department of Agriculture.

[74] W. S. Tower, cited above, Chs. VIII–IX.

was needed to check its rate of decline. This was supplied by an increased demand for whale oil originating with soap fabricators. This new change in the current of demand has apparently been sufficient to check the rate of decline of the whaling industry; though neither the revived esteem in which whale oil is now held, nor the new technology of whaling,[75] has sufficed to impart a fillip to the American branch of this industry—now virtually extinct. Whaling has passed largely into the hands of Norwegians, who in recent years have had remarkable success in the Antarctic regions where whales are still found in great abundance.

The cases of acceleration among lingering decadent industries are theoretically more important than those among progressive industries. As we have seen, the latter, when statistically reliable, generally reduce to retardation, the moment our measurements take account of structural changes in the status of industries.[76] However, the acceleration found in decadent industries whose decline has not been interrupted by a structural change cannot be resolved in this fashion. These cases of acceleration are 'real', and they are indicative of the slackening of progressive forces. For, if the pressure of technical or market factors did not relent, industries which had begun to decline would continue to do so and soon reach extinction; or else, as progressive forces within the industry continued to press, a structural change might take place in the declining industry, which—once rejuvenated—would embark on a new career of rapid growth and retardation.

8. Variation in the Rates of Retardation

Our earlier statistical survey disclosed, but left uninterpreted, the quantitative differences among the rates of re-

[75] See C. H. Townsend, "Twentieth Century Whaling," *Bulletin New York Zoological Society*, January-February, 1930.
[76] See pp. 154–5, and Appendix C. II.

tardation of the individual industries; for that survey was virtually restricted to the one purpose of establishing the generality, rapidity, and continuity of retardation in the ensemble of industries. Now that our analysis of the causes of retardation is completed, it is desirable to examine some of the general variations in the actual rates of retardation. Our sketch of the causes of retardation furnishes clues for interpreting these variations, and that sketch itself will gain support from a quantitative study of industrial differences. This study will be confined mainly to the continuous production series.

The rates of retardation of two groups of series earlier distinguished—'all' series and basic series, the first group including practically all of the second—are summarized in Table 28 and Chart 3. It will be observed that, on the average, the rates of retardation of the basic series are distinctly lower and more nearly uniform than the rates of retardation of the non-basic series.[77] These differences accord with what the general analysis of industrial retardation suggests. The series classed as 'basic' represent industries of considerable importance and of extensive reference, and in such industries strong tendencies are at work towards cancellation of the forces making for retardation by the forces making for acceleration. For instance, retardation in the consumption of a leading raw material by old industries, originating in either a retardation of their output or increased conserva-

[77] The difference between the basic and non-basic groups is greater than the frequency distributions may suggest, for the 'all' series group includes practically all of the basic group. A direct comparison of the rates of retardation for 59 basic series and 41 non-basic series shows the following: arithmetic mean for basic series, –0.9 per cent, for non-basic series, –2.0 per cent; median for basic series, –0.9 per cent, for non-basic series, –1.7 per cent. The measures of stage of retardation confirm the difference found between basic and non-basic series. (The composition of the various groups, except the non-basic, is set forth in Appendix A, Table 46, columns *e* and *f*. The numbers of the non-basic series are: 2–4, 8, 11–2, 16–7, 21–2, 30, 35, 37–8, 40–2, 44–5, 51, 54, 57, 61, 63, 65, 67, 69–70, 72, 75–7, 81, 84, 87–9, 94, 96, 98, and 103.)

Table 28

FREQUENCY DISTRIBUTIONS OF AVERAGE RATES OF RETARDATION, FOR 'ALL' SERIES AND BASIC SERIES

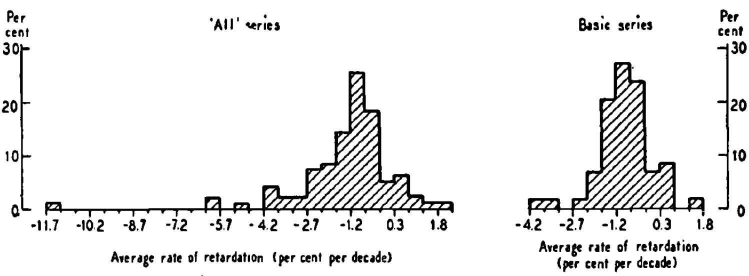
Average rate of retardation (per cent per decade)	'All' series		Basic series	
	Number	Percentage	Number	Percentage
Below −6.2*	1	1.0	..	...
−6.2 to −5.8	2	2.0	..	...
−5.7 to −5.3	..	...	..	...
−5.2 to −4.8	1	1.0	..	...
−4.7 to −4.3	..	...	..	...
−4.2 to −3.8	4	4.0	1	1.7
−3.7 to −3.3	2	2.0	1	1.7
−3.2 to −2.8	2	2.0	..	...
−2.7 to −2.3	7	7.1	1	1.7
−2.2 to −1.8	8	8.1	4	6.8
−1.7 to −1.3	14	14.1	12	20.3
−1.2 to −0.8	25	25.3	16	27.1
−0.7 to −0.3	18	18.2	14	23.7
−0.2 to 0.2	5	5.1	4	6.8
0.3 to 0.7	6	6.1	5	8.5
0.8 to 1.2	2	2.0	..	...
1.3 to 1.7	1	1.0	1	1.7
1.8 to 2.2	1	1.0	..	...
Total	99	100.0	59	100.0

*The item in this class is —11.5.

tion in the use of the material, will tend to be counteracted in considerable measure by the demand for the raw material originating with the 'new' and vigorously growing industries. The consequence is that the rates of retardation of the basic series are only moderately high in their general level and in the degree of their dispersion. The non-basic series, on the other hand, include a number of rather new industries, whose spectacular rates of growth in the early decades have since been sharply curtailed, so that their rates of retardation are very high. They include several retrogressive industries, decadent for some time, which have experienced abatement in their rates of decline, so that their rates of retardation are low. They include also several industries which only recently have entered the phase of decadence, so that their rates of retardation are high. On the whole, the non-basic series represent industrial activities whose growth has been subject to a smaller degree of counteraction of the

Chart 3

FREQUENCY DISTRIBUTIONS OF AVERAGE RATES OF RETARDATION OF 'ALL' SERIES AND BASIC SERIES



forces making for retardation by those making for acceleration than is found in basic series; for a restricted number of factors ordinarily dominate the impulses impinging on the development of individual non-basic industries—as when the demand for a raw material arises in few sources, or the demand for a finished product is subject to vagaries of fashion, or a commodity is produced under conditions of rapidly diminishing resources. The consequence is that the rates of retardation of the non-basic series, while higher in their general level than the rates of the basic series, show greater dispersion.

It is apparent from the comparison of the basic and non-basic series that there is some relation between the rates of retardation of production series and the degree of generality of their industrial reference. Of course, this relation is not disclosed very satisfactorily by a dichotomous classification, inasmuch as there are considerable differences in the degree of generality of the series in both the basic and non-basic groups. Though it is not feasible to attempt a more detailed classification of the series from the standpoint of their degree of generality or specificity, effective comparisons can readily be made in the case of commodities whose records of both production and industrial consumption are contained among the series analyzed. Since the consumption of a given raw material extends over a wide geographic area and is shared by a large number of industries, a consumption series has a wider (direct) industrial reference than a corresponding production series. Of the nine commodities [78] admitting of comparison—cotton, wool, flaxseed, copper, lead, zinc, gold, tobacco, and silver—only the last two show a higher degree of retardation in their consumption than in their production.[79] This difference accords with theoretical expectations. As the number of uses to which raw materials are put normally increases in a progressive national economy, the forces making for retardation tend to be checked, with the result that the rates of retardation of consumption series are generally only moderately high. But as the domestic branch of the production of a given commodity constitutes only a portion of the world output, the national industry may experience a relative decline in foreign demand, or, if it experiences checks from domestic resources, it may become more dependent on foreign supplies. Such circum-

[78] Also rails, but such a comparison has less meaning for this commodity.

[79] These comparisons are based on periods which are identical for the production and consumption of each commodity, but different for the several commodities. Special computations of rates of retardation were necessary for certain of the series. They are as follows for the periods indicated: copper (1883–1929), -2.2 per cent; zinc (1873–1929), -1.4 per cent; silver (1880–1929), -1.0 per cent; gold (1880–1929), -2.4 per cent; and raw tobacco (1880–1929), 0.2 per cent.

stances are very likely to arise in what was once a swiftly progressive branch of a world industry; and when they eventuate, the rate of retardation in domestic production will be 'rapid'.

The industries covered in our statistical survey are of varying degrees of maturity. The age of an industry has considerable bearing on its rate of retardation, but the relation between the two is not simple. Most of the 'new' industries are found among those having the highest rates of retardation, but so are many 'old' industries. Some 'old' industries in an advanced stage of decadence actually show acceleration, and so do a few 'new' industries. This lack of uniformity in the relation between the age of an industry and its rate of retardation can be explained in terms of the preceding theoretical analysis. New industries grow very rapidly at the start, but their early pace is not long maintained; for as the new industries advance, they are subjected to increasing pressure by the older industries and the industries which are newer still. However, not all 'new' industries evidence growth at a rapidly diminishing rate; for a revolutionary stimulus will occasionally impinge even on a relatively new industry, and if that industry be observed over a period including portions of the two epochs marked off by the revolutionary change, mild retardation or even acceleration is likely to be found. As for those 'old' industries which have already vanished or which seem to be approaching extinction, it is self-evident that their rates of retardation will be very high. On the other hand, those 'old' industries which linger on are likely to show abatement in their rates of decline; the very fact that they persist is indicative of a slackening in the pressure of progressive forces.

Perhaps the best, though not a really good, statistical index of the 'economic age' of an industry is its average rate of growth. As we have seen, various causes occasionally make for the coincidence of a rapid rate of growth and a low rate of retardation in an industry, or of a low rate of growth and rapid retardation. However, as a general rule, the industries which have grown most rapidly show the most rapid rates of retardation, and the industries which have grown least rapidly the lowest rates of retardation. The coefficients of correlation in Table 29, especially for the 'II' groups which are

Table 29

COEFFICIENTS OF CORRELATION BETWEEN AVERAGE RATES OF GROWTH AND AVERAGE RATES OF RETARDATION, FOR SEVERAL GROUPS OF PRODUCTION SERIES

Group	Coefficient of correlation
'All' series	
(I) 99 series	-.63
(II) 88 series	-.68
Basic series	
(I) 59 series	-.30
(II) 55 series	-.59
Nonagricultural series	
(I) 75 series	-.59
(II) 65 series	-.59
Basic nonagricultural series	
(I) 46 series	-.30
(II) 42 series	-.59

the most significant,[80] indicate that this relationship is fairly close. In reading the coefficients it must be remembered that a negative rate of 'retardation' denotes retardation proper,

80 For the composition of the several groups of series for which coefficients of correlation are given in Table 29, see Appendix A, Table 46, columns *e*, *f*, *g*, and *h*. The 'I' groups are those described in the Appendix. The 'II' groups are statistically more significant than the 'I' groups. The 'II' groups are more 'homogeneous', as they exclude (according to the composition of the several

while a positive rate of 'retardation' denotes acceleration. The coefficients of correlation are negative and fairly high; this means that, on the average, industries with relatively high rates of growth have experienced relatively marked retardation, and industries with low rates of growth limited retardation. Rapid industrial growth has been attained, generally, at the cost of a rapid decline in the rate of growth; or to put it more accurately, the growth of industries has tended to be self-effacing to the extent of their growth.

IV. ON A LAW OF INDUSTRIAL GROWTH

Our study of the tendency of industries to grow at a declining rate has encompassed a considerable variety of industries observed at various stages in their life histories. Many of the industries are still growing vigorously, others have passed their apex, some are practically extinct, and at least one decadent industry has recently experienced rejuvenation. Having studied industries from the standpoint of their development during a fixed period, we have observed only a segment of the life history of each. May we not, however, combine our partial visions of the development of individual industries into a general view of the typical life history of an industry?

Following writers on biology and population, some economic statisticians have come in recent years to speak of a

groups) the following: (a) several series representing industries which have received a revolutionary stimulus to accelerated development—rubber imports, cigarettes, petroleum, sulphur, rice; (b) series whose 'coordinates' are so large that they are likely to exercise an excessive influence on the correlation coefficients—aluminum, Portland cement; (c) series which have a very defective statistical constitution from the standpoint of a study of the relation between growth and retardation—shares traded, postage stamps, locomotives, unmanufactured silk imports (see Appendix C, I-II). The coefficients for the groups from which these exclusions were made are summaries of rather compact 'scatters'. That the coefficients could not result from differential clustering of distinct industry groups is indicated by the various coefficients in Table 29; tests by the method of subdivision, more detailed than those recorded in the table, also pointed to the conclusion of statistical significance.

'law of growth' in industries and to give this 'law' mathematical expression in the form of 'growth curves'. These curves differ with the investigator, but they have one fundamental feature in common: they approach with increasing closeness a fixed maximum value—in mathematical terms, a horizontal line as an asymptote, and in market terms, a saturation point. The various 'growth curves' have some philosophic basis in postulating limits to industrial expansion; for the conception of indefinite growth of industries can neither be supported by analysis nor by experience. But 'growth curves', when applied to industries, are arbitrary in covering the period of advance alone; for many of the causes impinging on an industry are likely to be the same during the period of decadence as during the period of advance. In the course of the life history of an industry, forces making for advance always act in combination with forces making for decadence, their balance determining whether a rise or decline takes place. Once the forces making for decline continue to gain in relative strength, they will at some point come to equal and then surpass the forces making for advance; so that the rise will culminate in an apex and be succeeded by a decline. It is difficult, therefore, to find any sound rational basis for the notion that industries grow until they approximate some maximum size and then maintain a stationary position for an indefinite period. Nor is the notion at all supported by experience: the production records of our industries practically never evidence a plateau at the apex: once an industry has ceased to advance, it rarely remains at a stationary level for any length of time, but rather soon embarks on a career of decadence. It is possible, of course, to formulate a 'law of decline', give it expression in a 'senescence curve', splice this curve on to a 'growth curve' at the apex, and in this way achieve a complete description of an industry's development. But such procedure is arbitrary, even unsound if it presupposes a break in the underlying causation, and it involves an inelegant mode of mathematical expression. Both analysis and history require that if a 'law of growth' of industries is to be formulated, it should be sufficiently general to subsume the periods of both advance and decline.

One of the most salient features of the long-range histories of industries is that their percentage rates of growth tend to decline. In this study, we have grasped the facts of industrial retardation and given them unity through the summarizations yielded by, what is in effect, a 'logarithmic' parabola.[81] When its second derivative is negative, this mathematical function will subsume both the rise and decline of given industries, and it may therefore be considered as the 'law of growth' which industries 'obey'. But this is true in so rough a sense that little is to be gained from the conception. If we had complete records of the life histories of many industries, we would almost certainly find that a 'logarithmic' parabola could describe accurately the entire development of very few industries, and that any other single mathematical curve would serve the task just as badly. The fact that several investigators have found that certain simple functions describe satisfactorily the growth of many industries is of little relevance; for these investigators have worked with mere segments of the histories of industries, and almost exclusively with progressive segments at that—all of which is natural enough, since the production of decadent industries is scantily recorded, and the industries which chiefly attract attention are still progressive.

We may restrict the formulation of a 'law of growth' to a mere statement of the principle of decline in the per-

[81] It may be noted that the 'normal curve of error' is obtained when we take antilogs of a parabola fitted to logarithms of production data and natural time units.

centage rate of growth in individual industries; but even this requires qualification. In the first place, the rule of retardation does not hold in the stage of late decadence of some industries. In the second place, there are fair grounds for believing, though our statistical records give us little assistance on the point, that the same is true of the stage of infancy of many industries. When an industry is still in a 'precommercial stage', its rudimentary technical problems being only partly solved and its financing inadequate, it is likely to oscillate between no production at all and only a nominal volume of output, and to show, on the whole, acceleration rather than retardation. Apparently, this has been the case in the beet-sugar, cottonseed-oil, and tin-plate industries. In the third place, the rule of retardation does not hold throughout for the secular trends of even established industries, though it does hold for their primary trends—which are movements of longer duration than secular trends. And in the fourth place, when as a result of a structural change, a progressive industry is invigorated or a senescent industry rejuvenated, the rule of retardation will hold for the period preceding and also for the period following the structural change, but it may not hold for a period overlapping the two.

Barring structural changes, the course of the life history of a typical industry may be divided into a number of 'stages'. But irrespective of the number of stages of industrial development that may be distinguished, or how they may be defined, given stages will be found to differ in duration and intensity from industry to industry, as will the relative durations of the several stages. Thus, the stage of industrial 'nascence' was long in the beet-sugar and cottonseed-oil industries, but short in the aluminum and rayon industries. The stage of industrial 'maturation' extended over several centuries in the lumbering industry, over several decades in the wire-nail industry, but only over several years in the miniature-golf industry. The stage of 'decadence' has been rather long in the whaling industry, but brief in the iron-rail industry. Nor are the stages of industrial decline often symmetrical with the stages of advance. So diverse are the patterns of the development of industries that only this rule of uniformity can be allowed: an industry tends to grow at a declining rate, its rise being eventually followed by a decline. And even this general statement must be read in the light of the various qualifications to the rule of retardation enunciated in the preceding paragraph, and in the light of the further qualification that progressive industries are occasionally terminated at what is historically their apex—as when they are proscribed by law.

But if the life history of an industry is considered as consisting of a rise and decline, there are substantial grounds for believing that the life histories of industries are becoming shorter. An increasing share of our production is assuming the form of 'luxuries', 'superfluities', and 'style goods'. The demand for such products is determined in large part by caprice, and does not have the stability which staples enjoy. Since our statistical survey is restricted to industries of long duration, it throws practically no light at all on the changing period of the life histories of industries; though it is possibly of some significance that industries engaged in the production of rather specific commodities show often the very highest rates of retardation. There is considerable room for serious inquiry into the changes in the period of the life histories of industries; but such a study will be handicapped by the paucity of data, and the technical difficulty of distinguishing commodities according to the degree of their specificity.